This is CS50.

CS Concentration Advising

Tuesday March 10
11:30am-12:30pm
Maxwell Dworkin Ground Floor

cs50.brianyu.me

Week 5

- Data Structures
- Linked Lists
- Trees
- Hash Tables
- Tries

What questions do you have?

Questions

- Why do we use malloc
- Tries
- Manipulate pointers in linked lists
- Coming up with hash functions

Today

Linked Lists

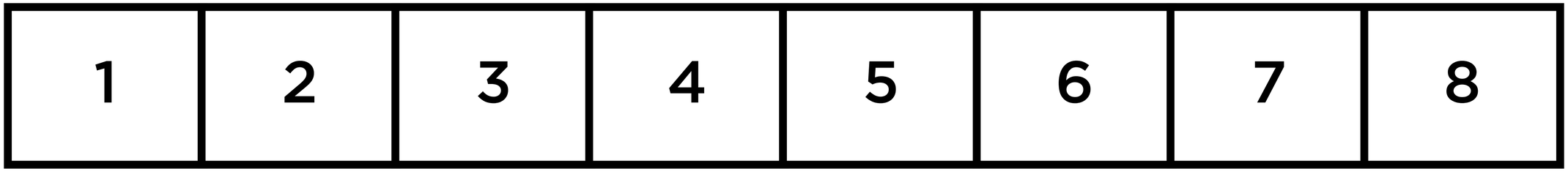
Hash Tables

Trees and Tries

Part One

Linked Lists

Arrays


1
2
3
4
5
6
7
8

Arrays

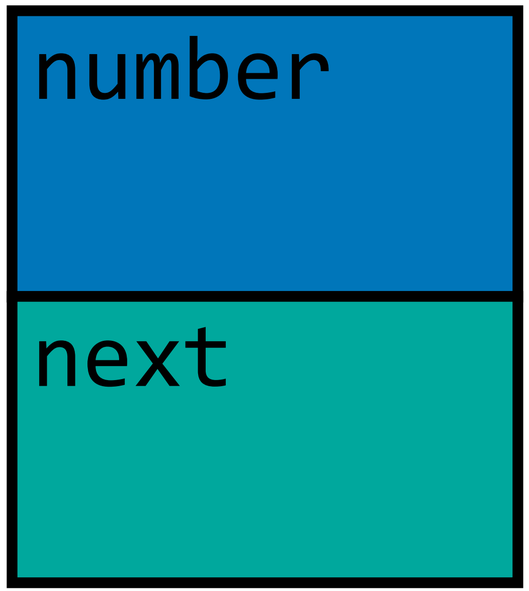
- Fixed size
- Contiguous in memory

Linked Lists

- Any size
- Not contiguous in memory

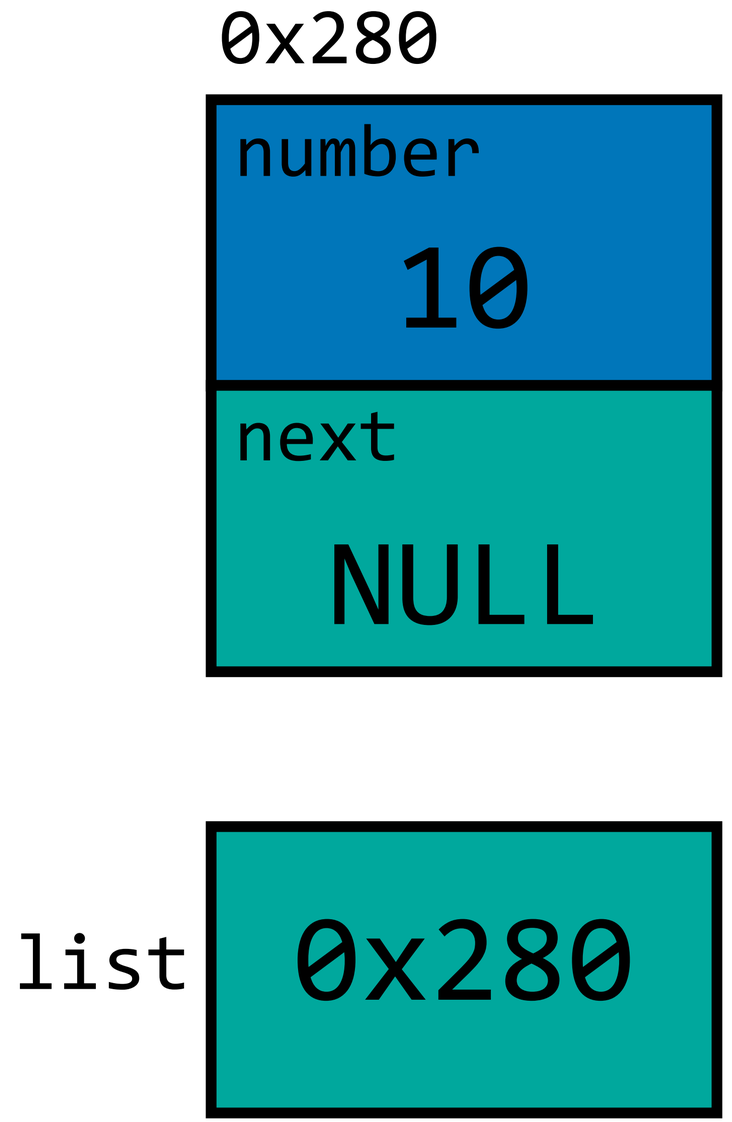
Linked List

```
typedef struct node
{
    int number;
    struct node *next;
}
node;
```

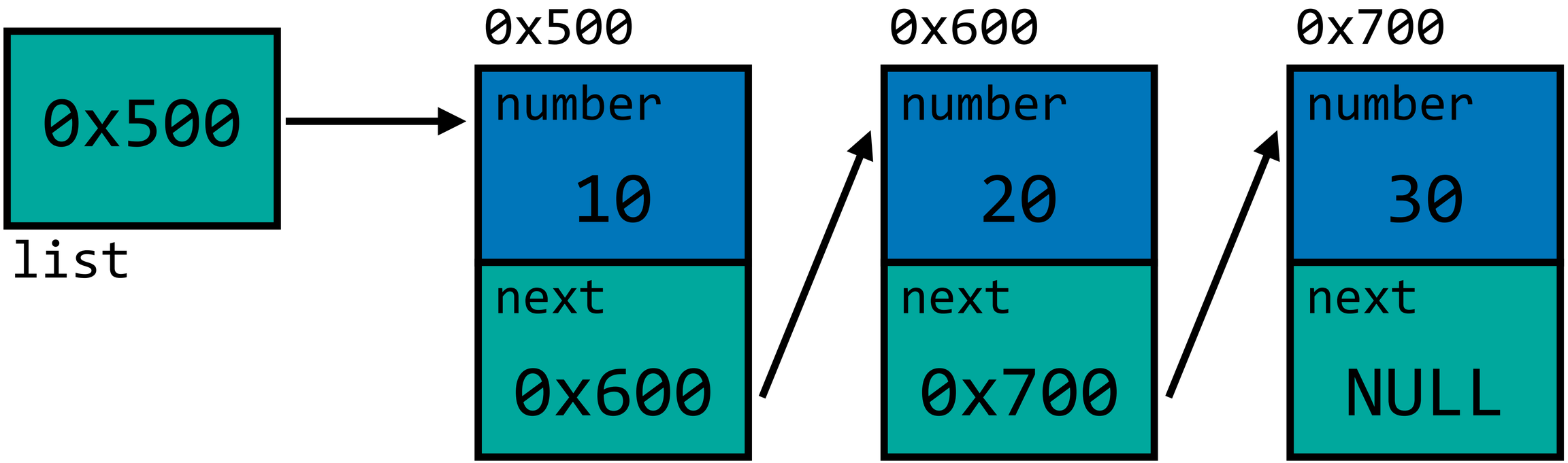


Linked List

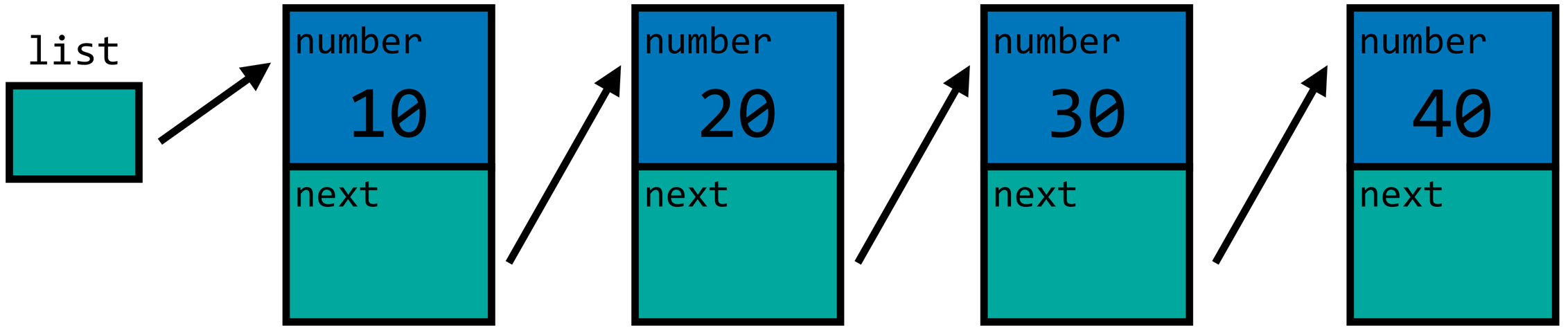
```
node *list = malloc(sizeof(node));

list->number = 10;

list->next = NULL;
```



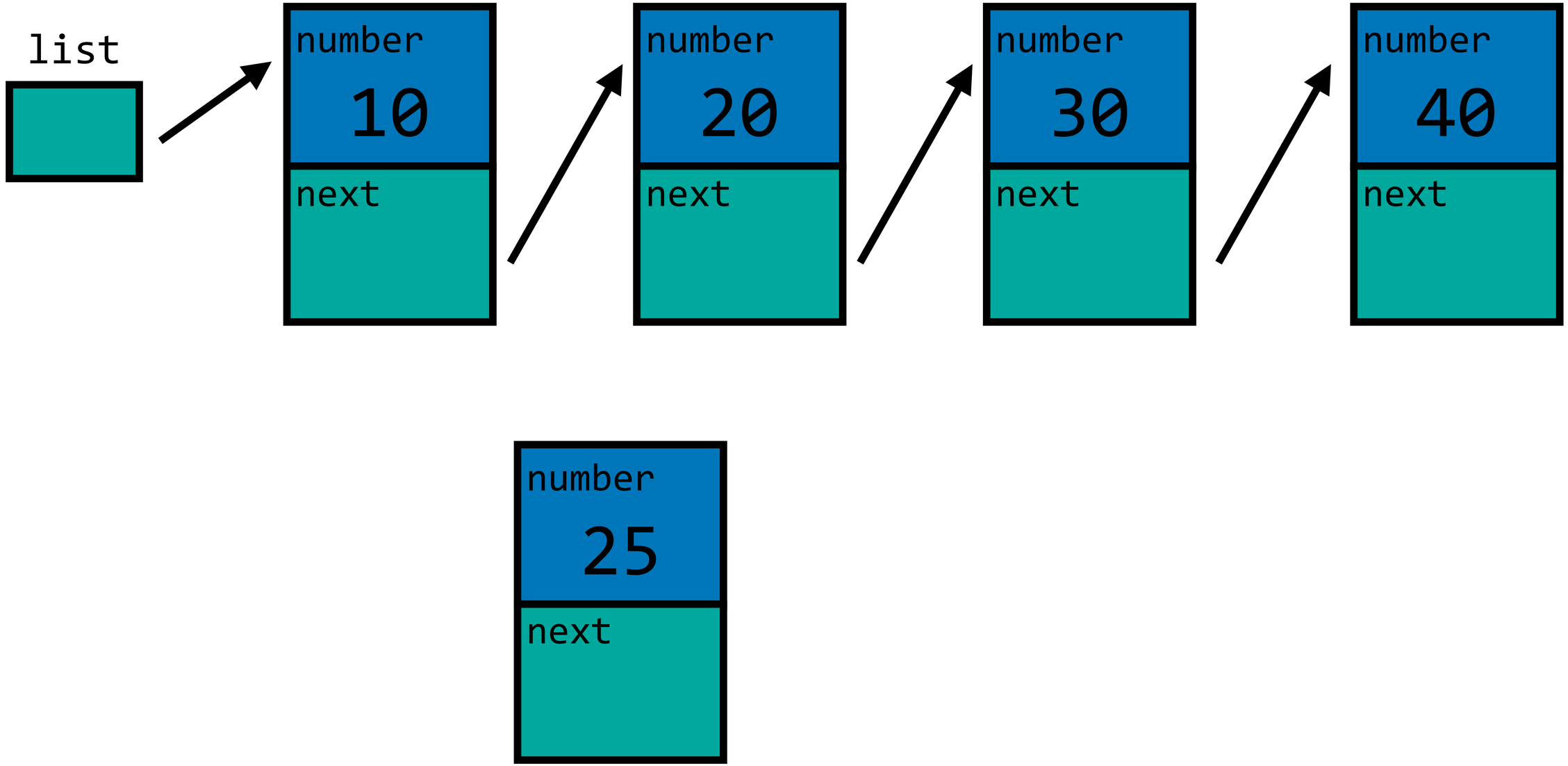
Linked List


0x500
list
0x500
number
10
next
0x600
0x600
number
20
next
0x700
0x700
number
30
next
NULL

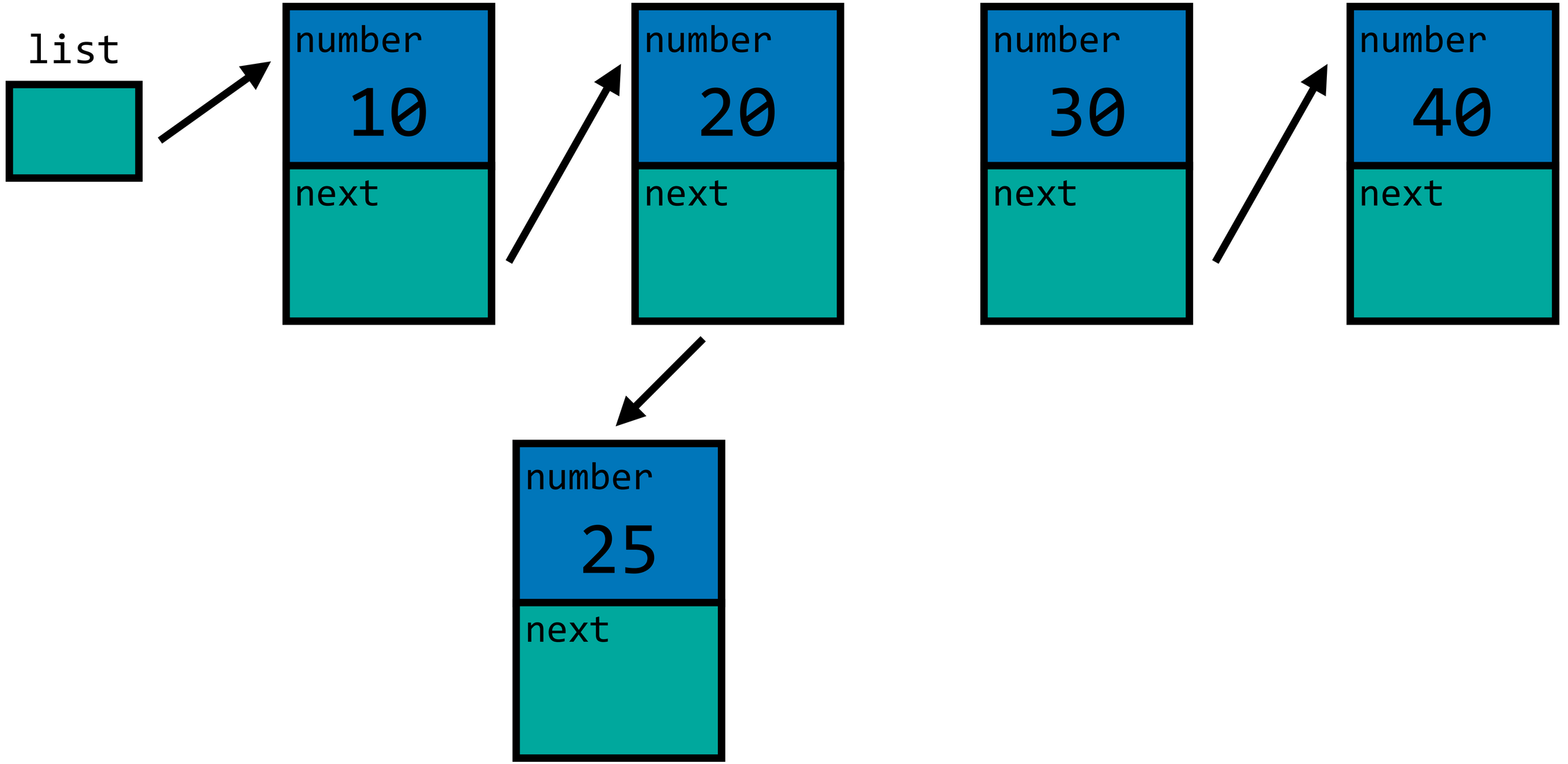
Insertion


list
number
10
next
number
20
next
number
30
next
number
40
next

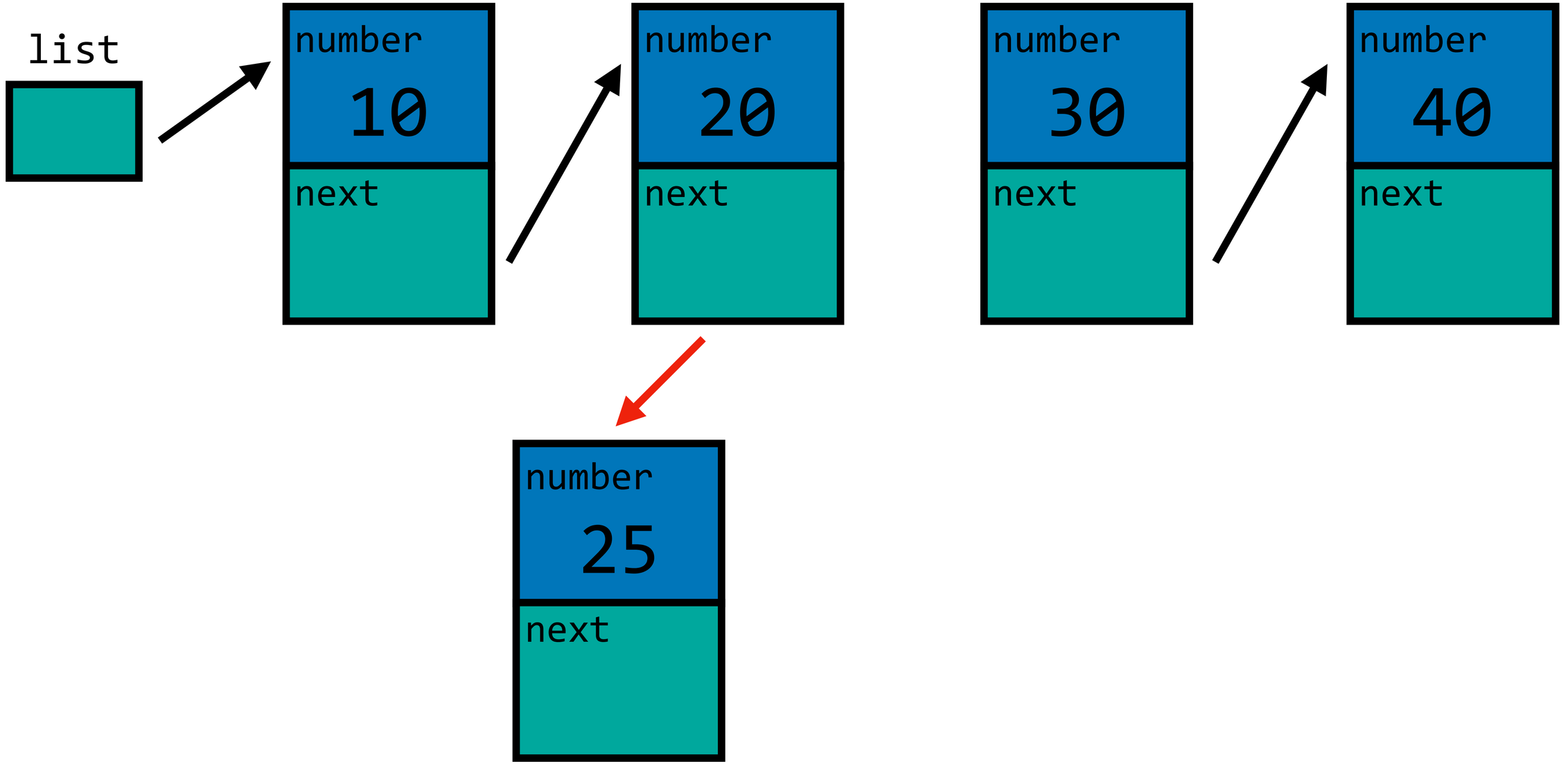
Insertion


list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

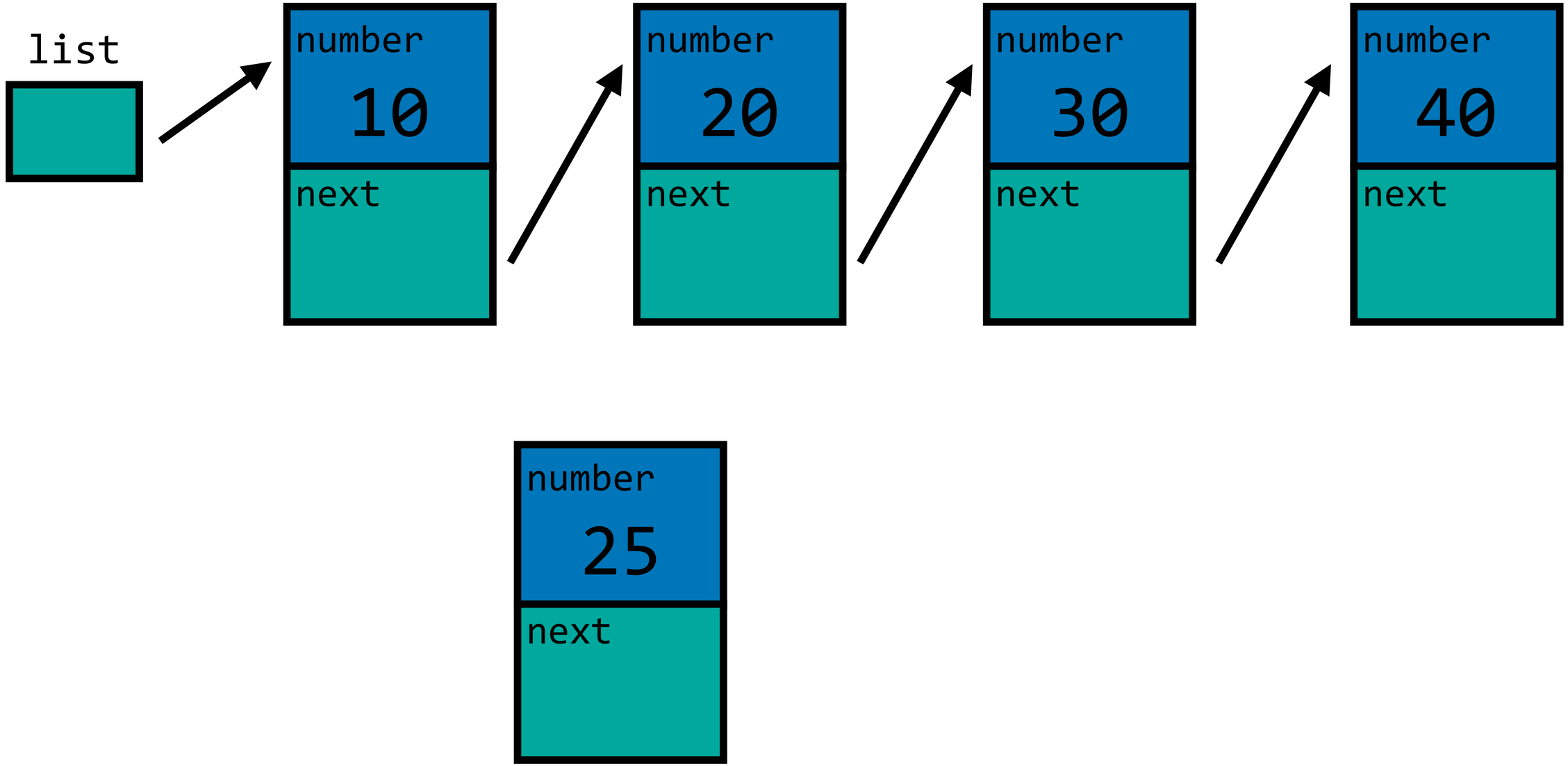
Insertion


list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

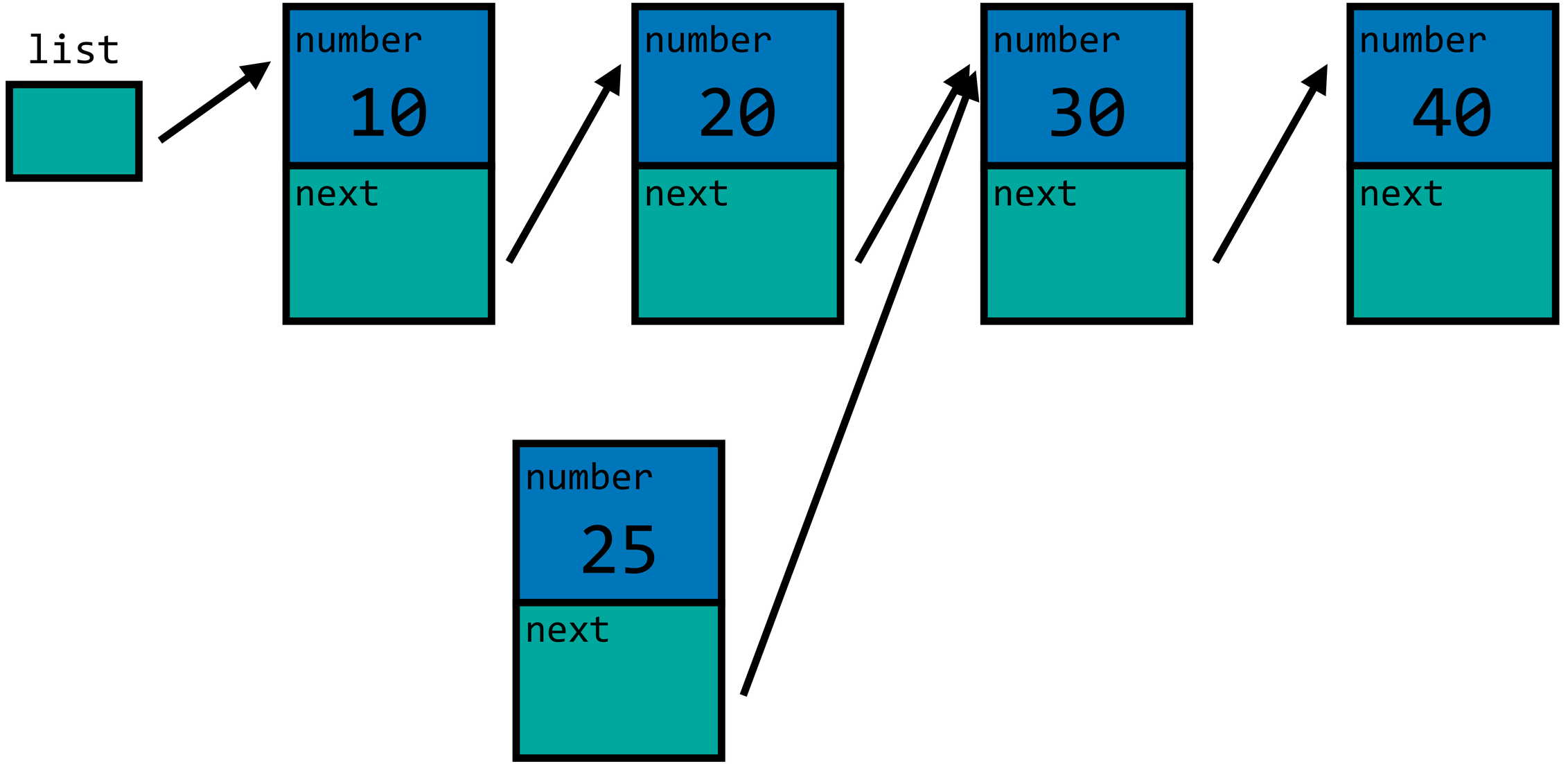
Insertion


list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

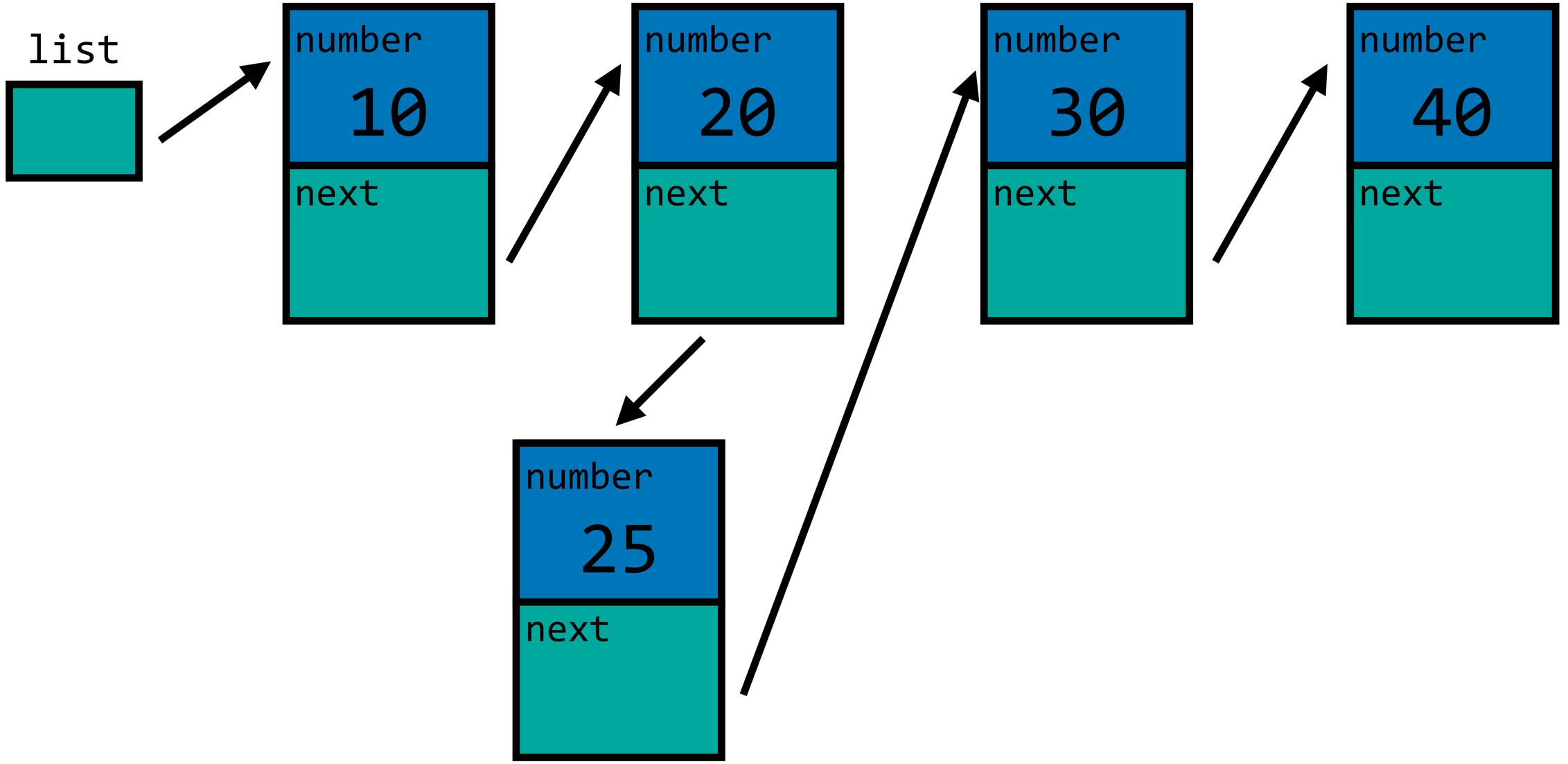
Insertion

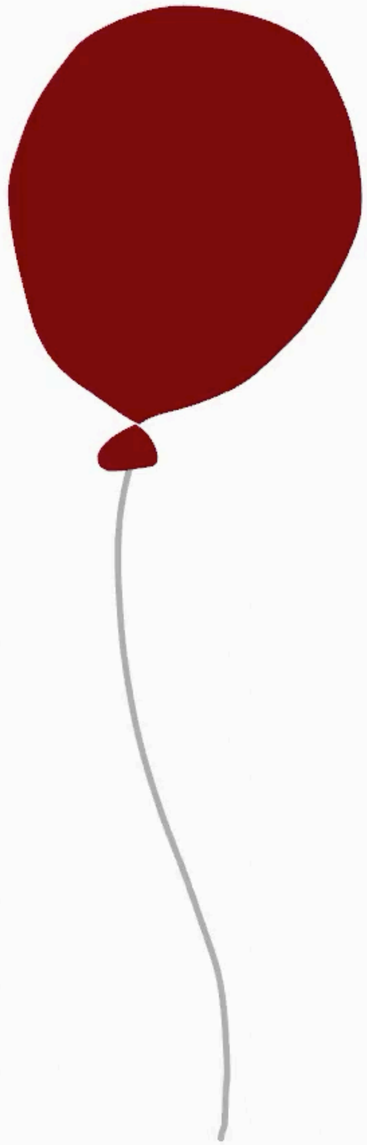

list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

Insertion

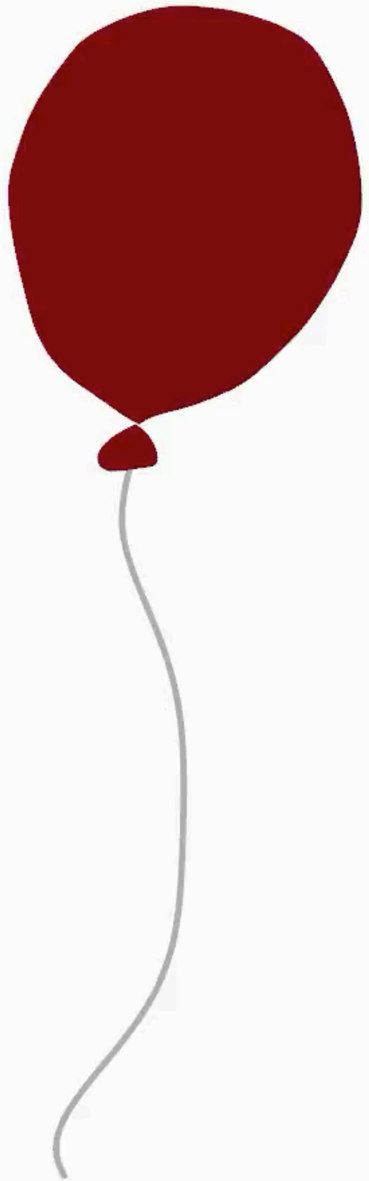

list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

Insertion


list
number
10
next
number
20
next
number
30
next
number
40
next
number
25
next

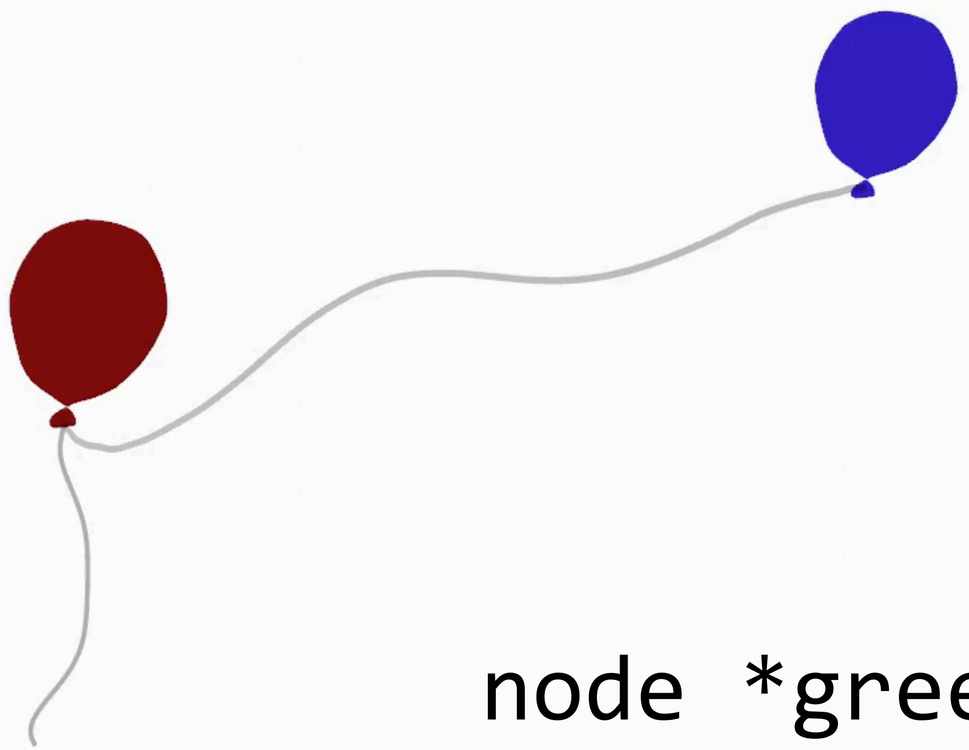


node *red

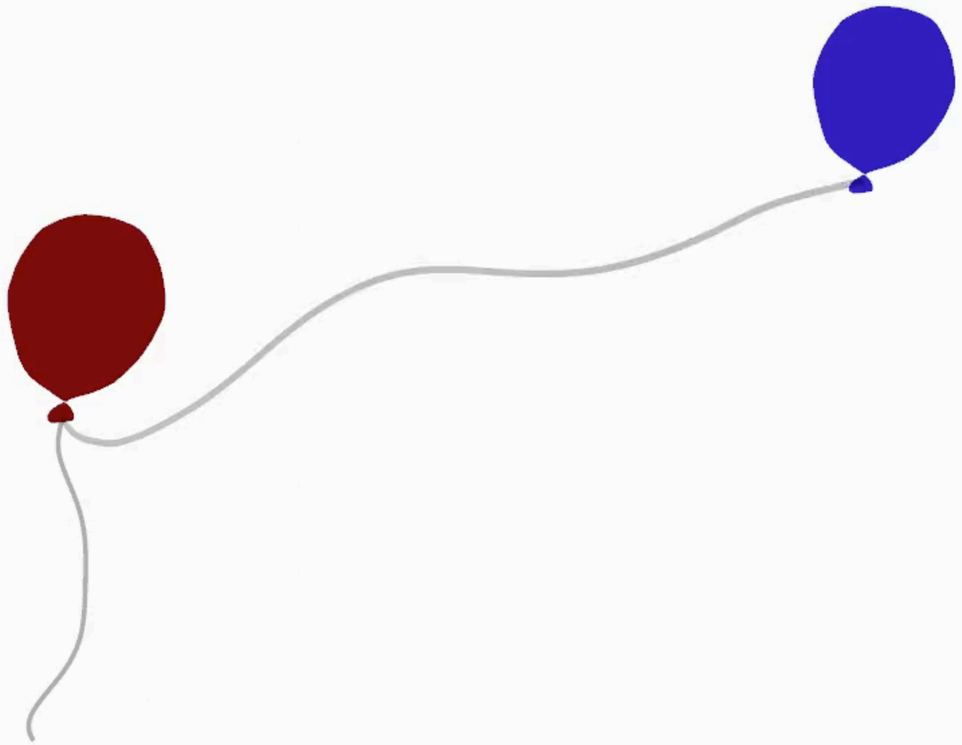


```
node *blue = malloc(sizeof(node));
```

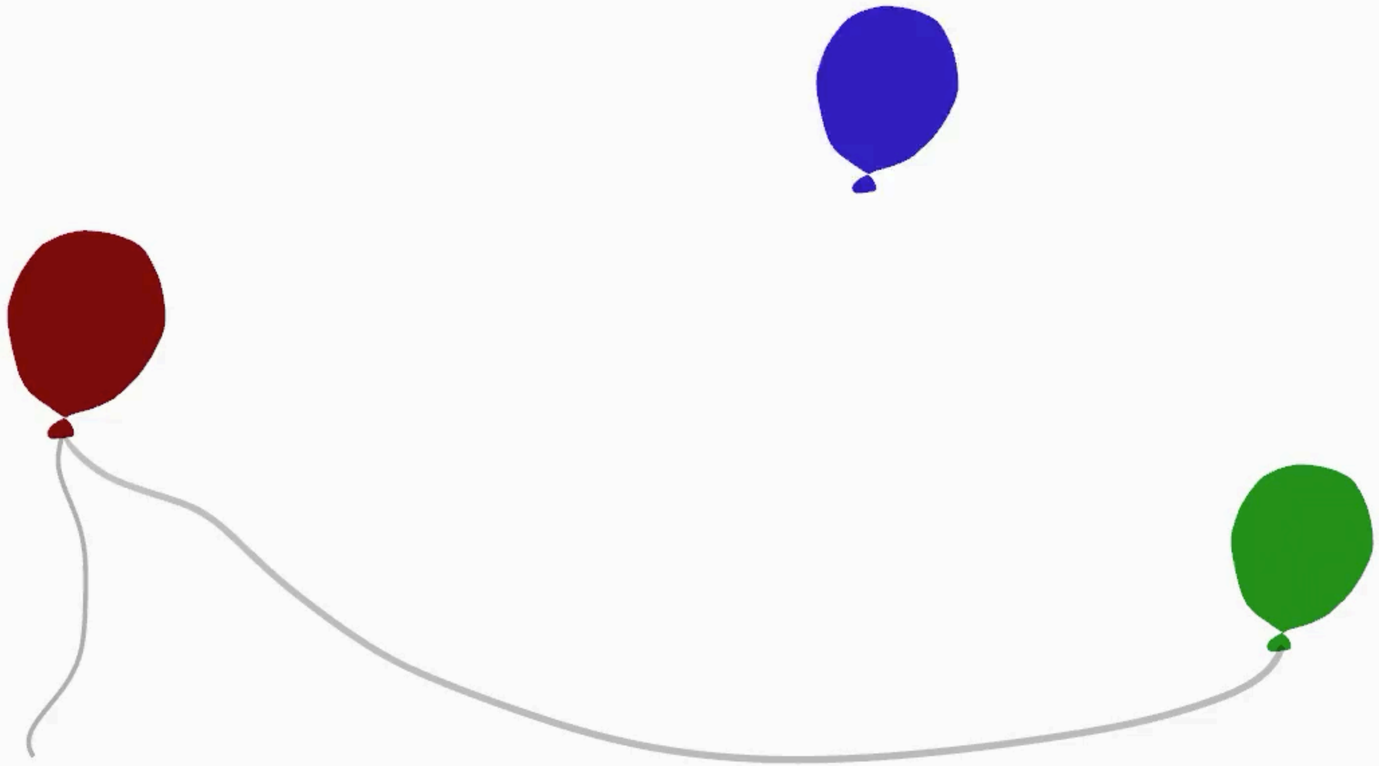
```
red->next = blue;
```

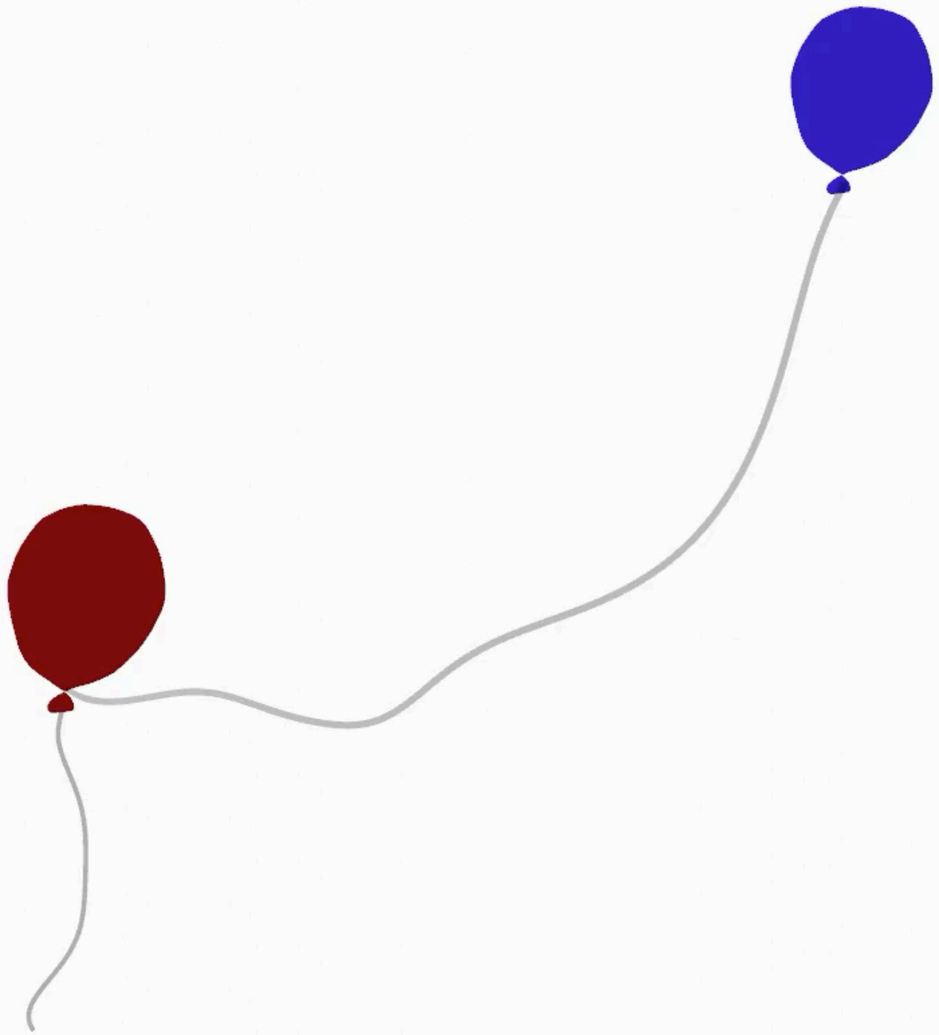


```
node *green = malloc(sizeof(node));
```

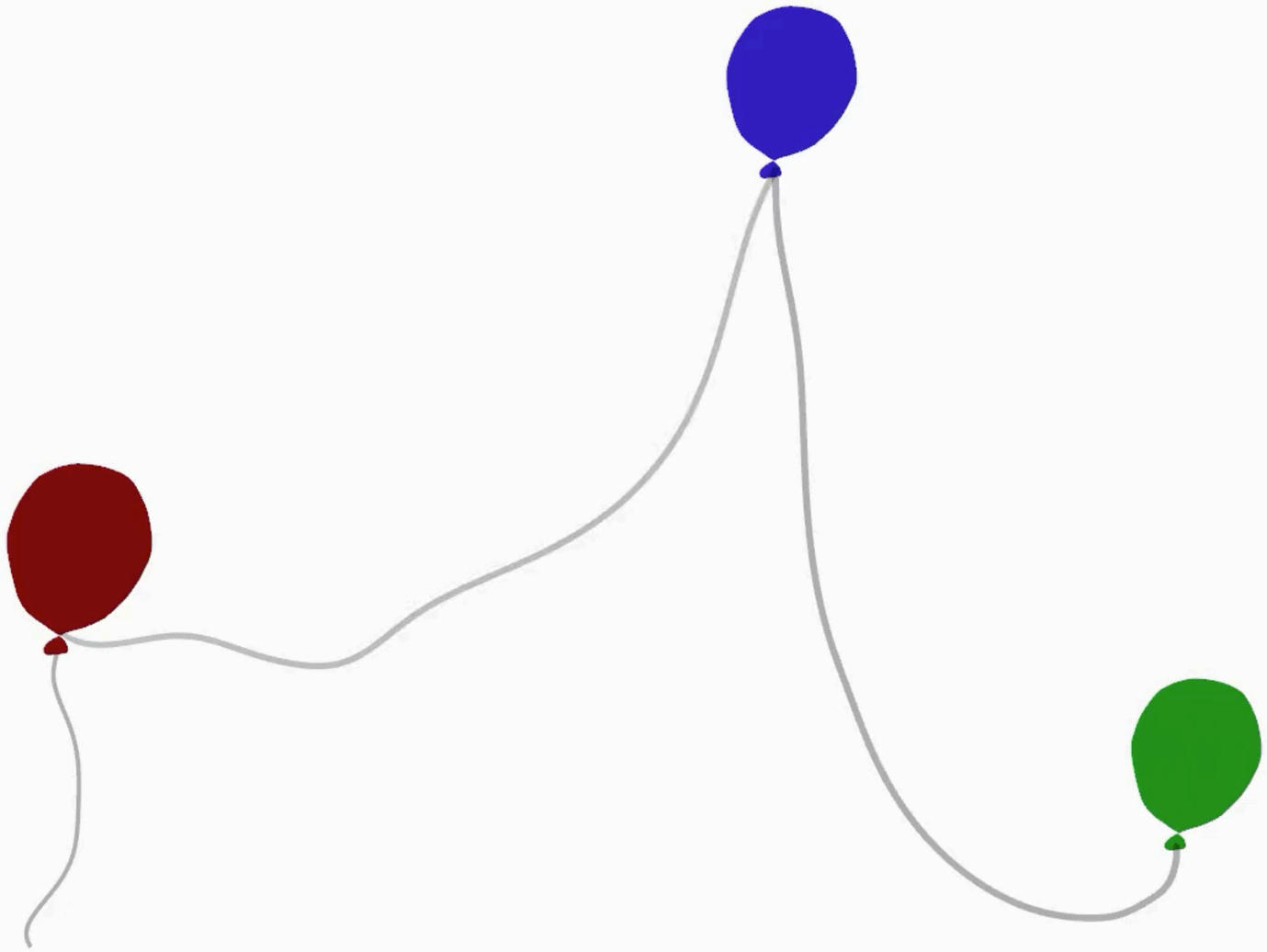


```
red->next = green;
```

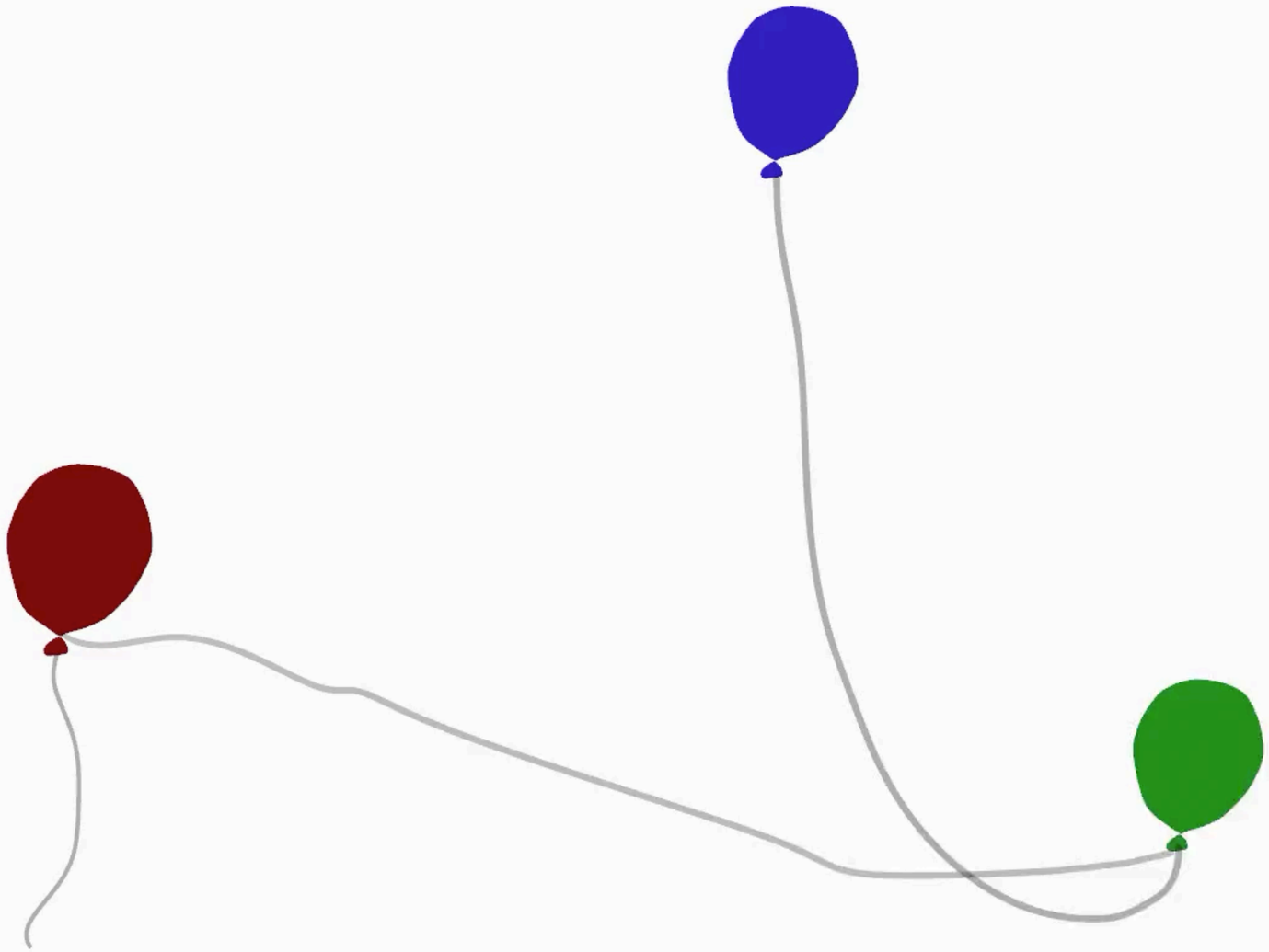




```
green->next = blue
```

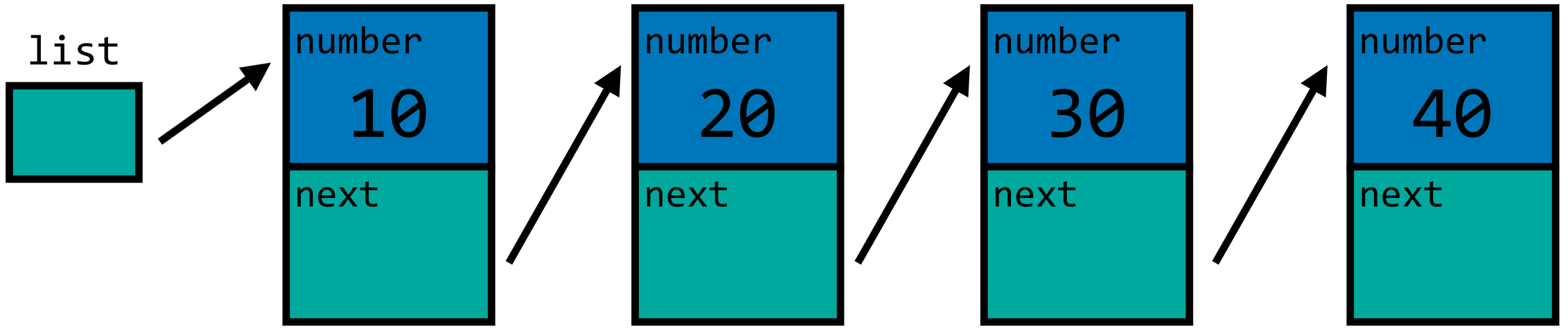


```
red->next = green
```

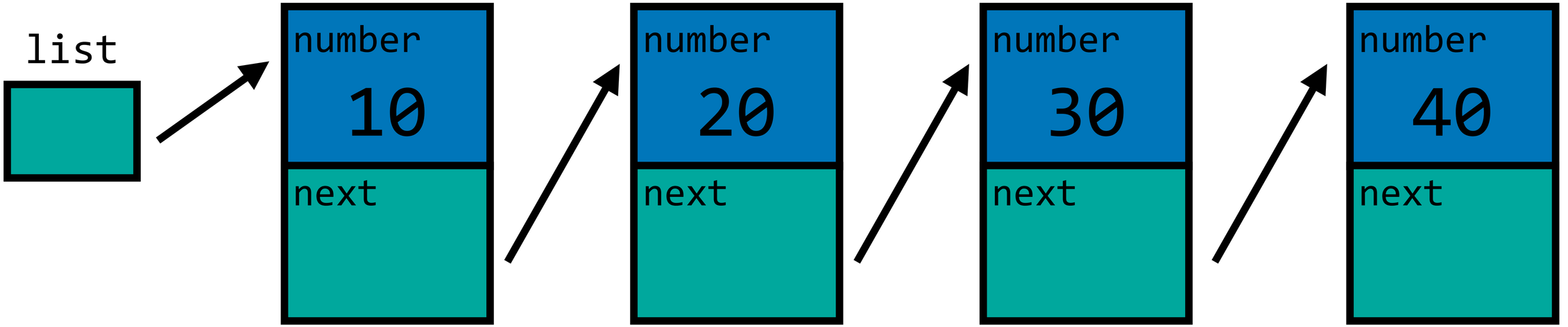


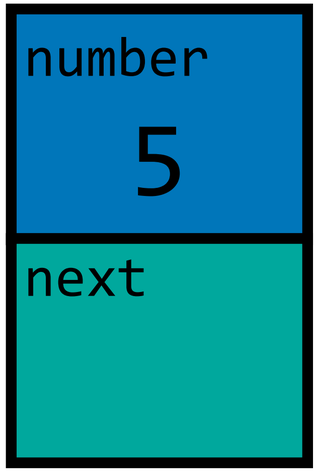
```
free(red);
free(green);
free(blue);
```

Insertion

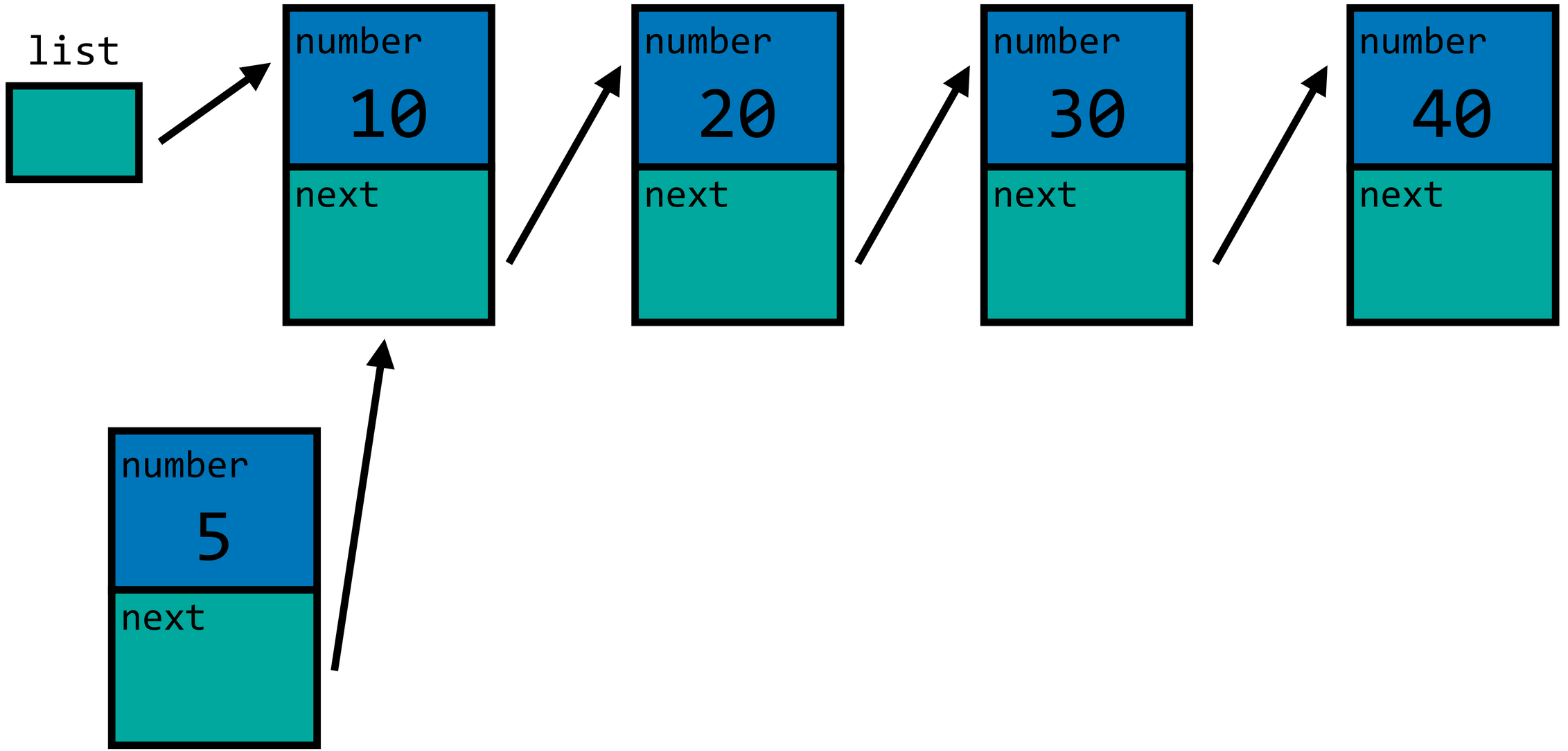

list
number
10
next
number
20
next
number
30
next
number
40
next

Insertion

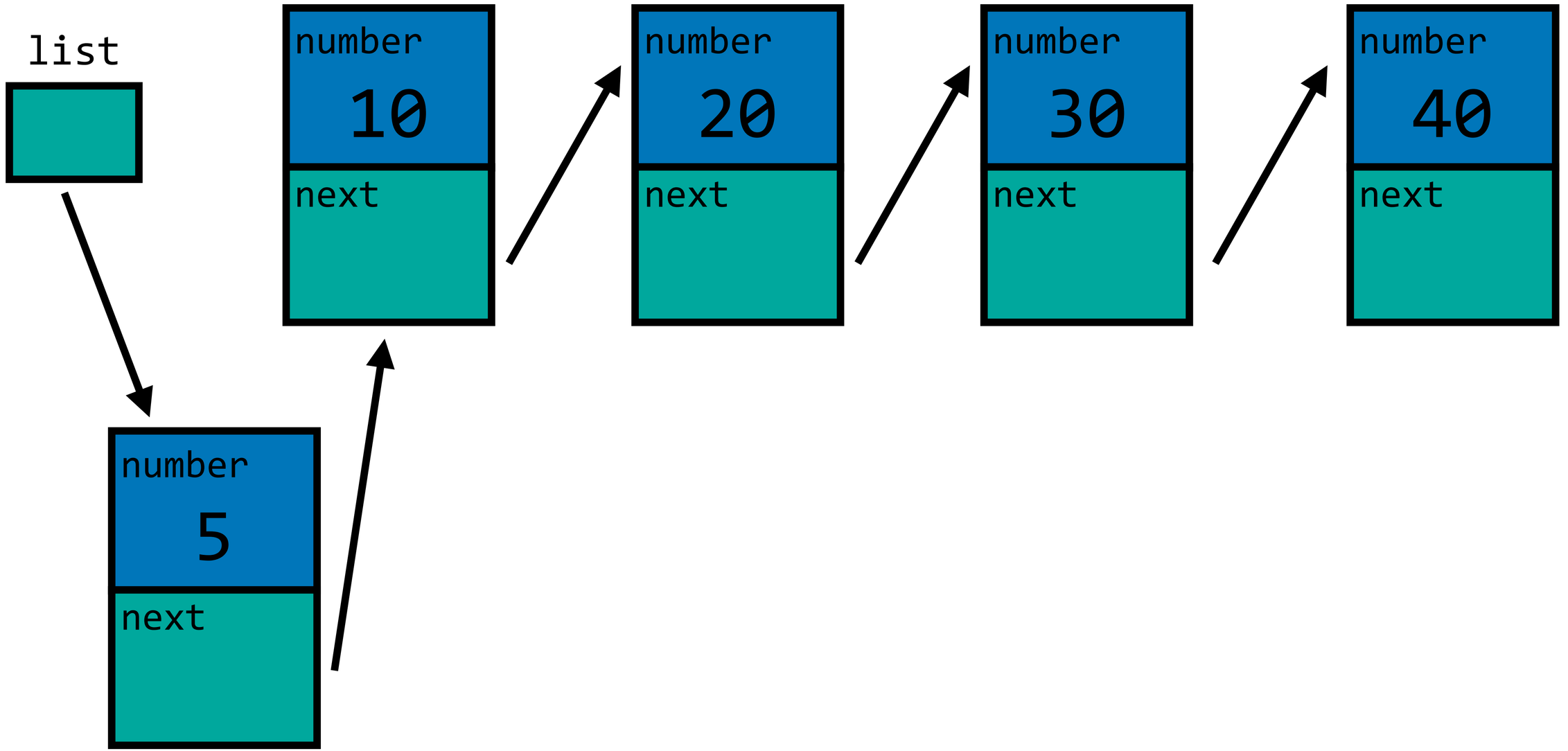

list
number
10
next
number
20
next
number
30
next
number
40
next


number
5
next

Insertion

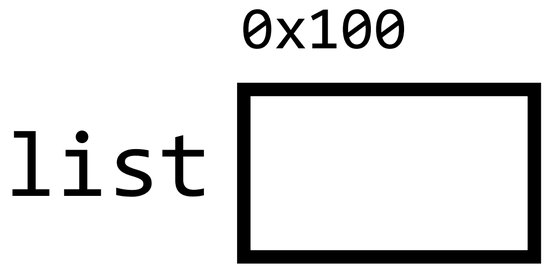

list
number
10
next
number
20
next
number
30
next
number
40
next
number
5
next

Insertion

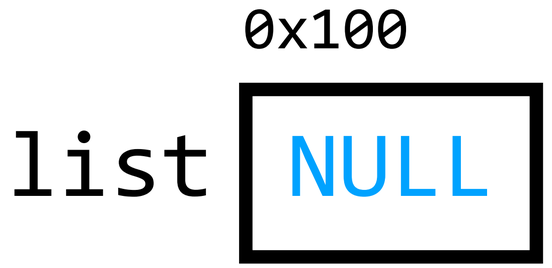

list
number
10
next
number
20
next
number
30
next
number
40
next
number
5
next

```
node *list = NULL;
```

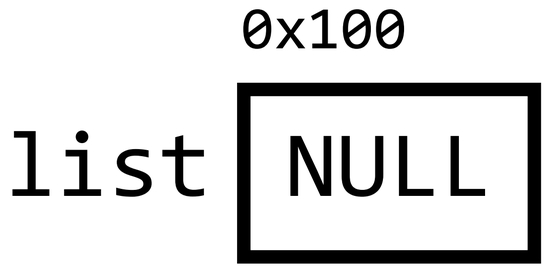
```
node *list = NULL;
```



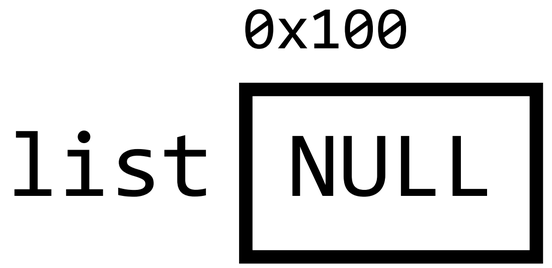
```
node *list = NULL;
```

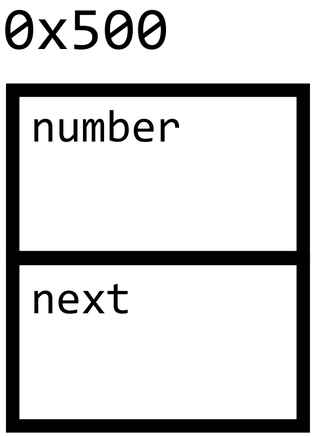


```
node *list = NULL;
node *n = malloc(sizeof(node));
```

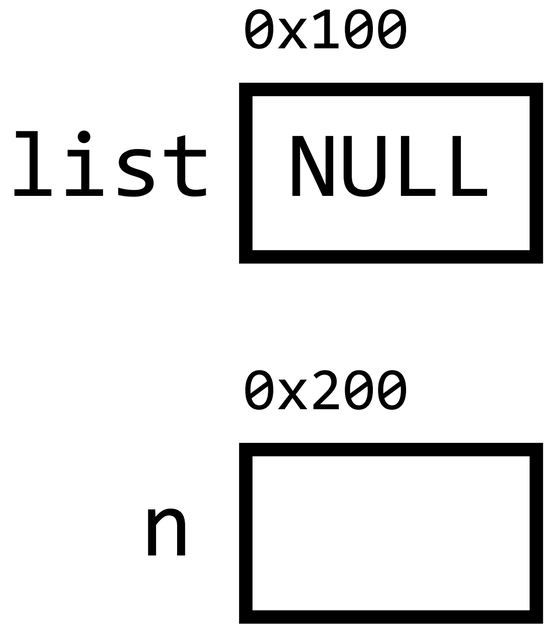


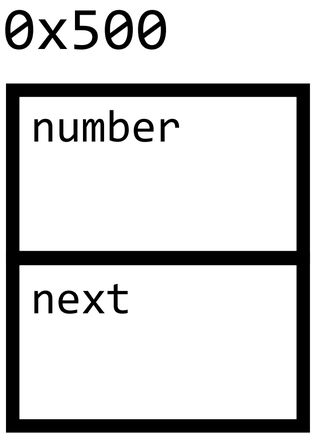
```
node *list = NULL;
node *n = malloc(sizeof(node));
```



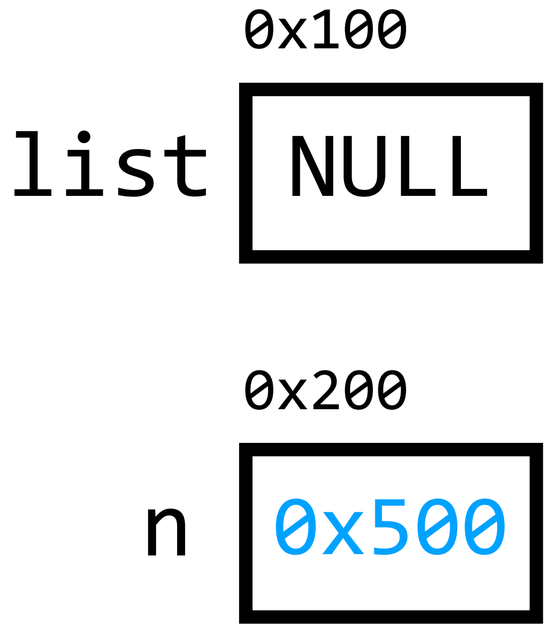


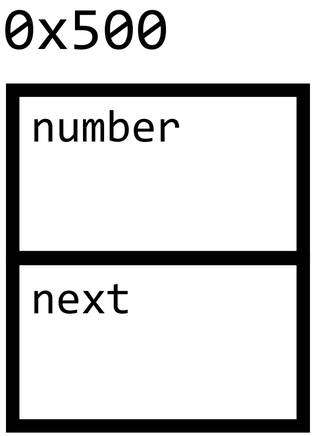
```
node *list = NULL;
node *n = malloc(sizeof(node));
```



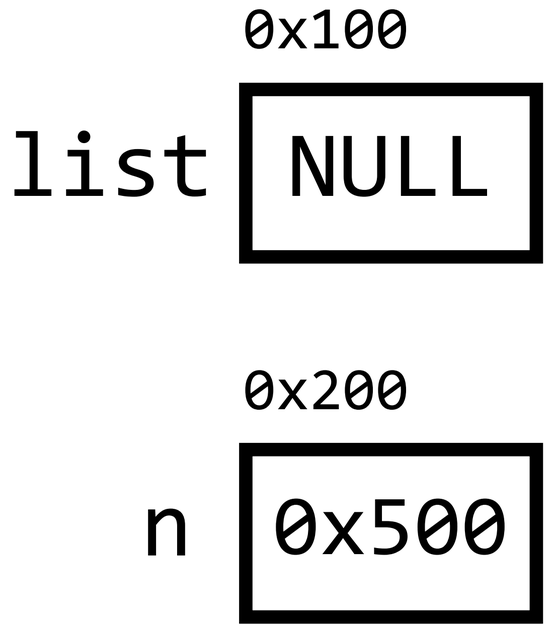


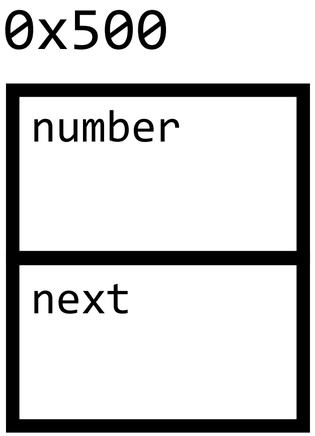
```
node *list = NULL;
node *n = malloc(sizeof(node));
```



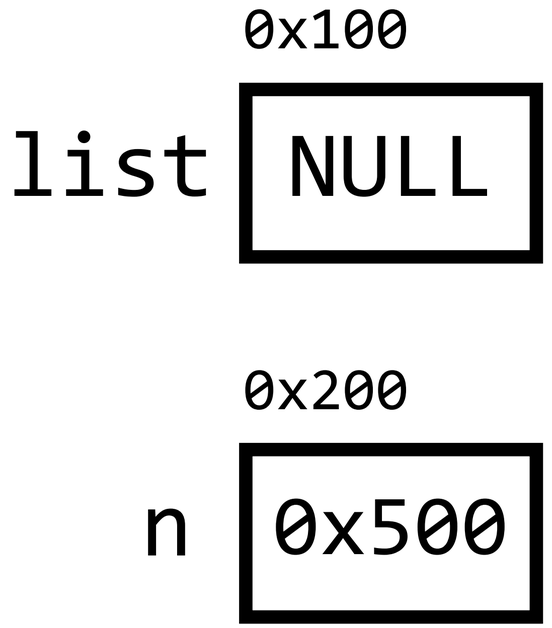


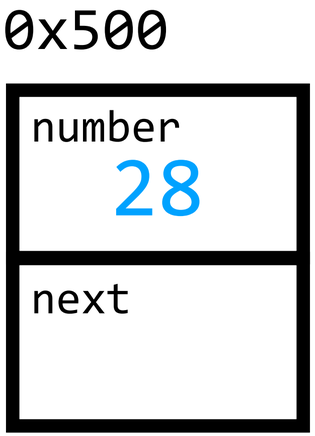
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
```



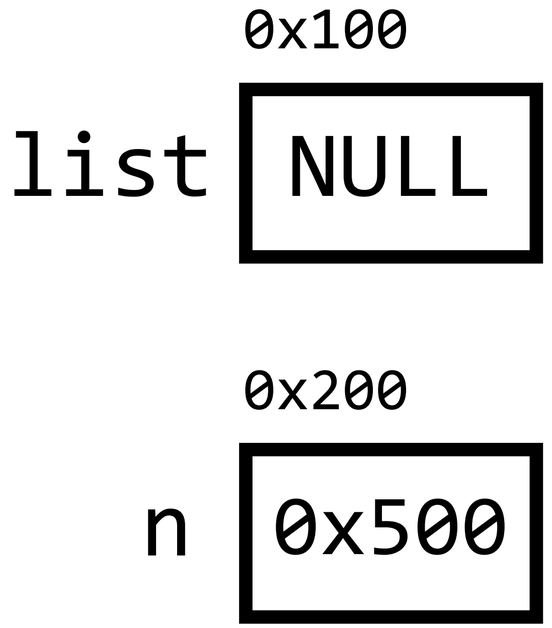


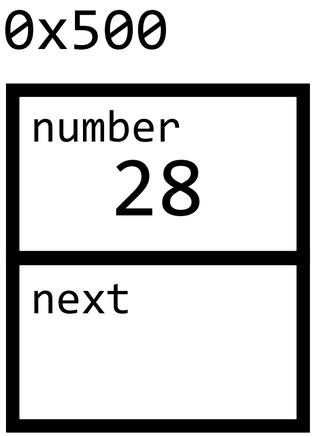
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
```



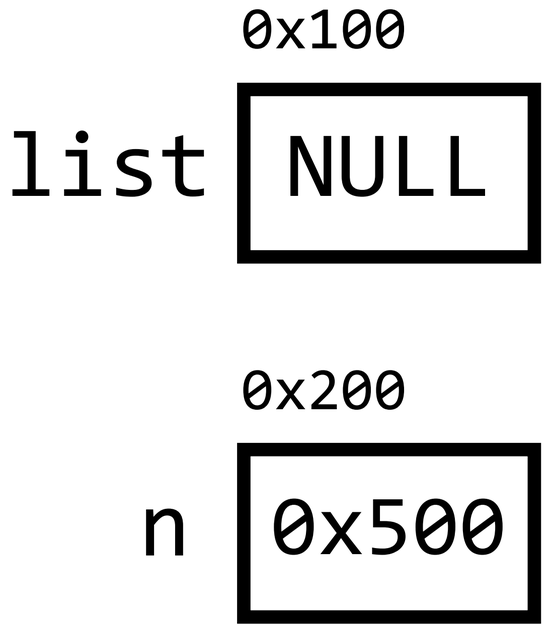


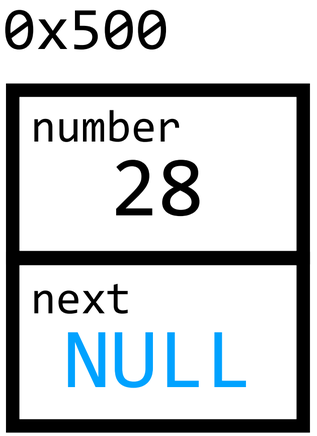
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;
```



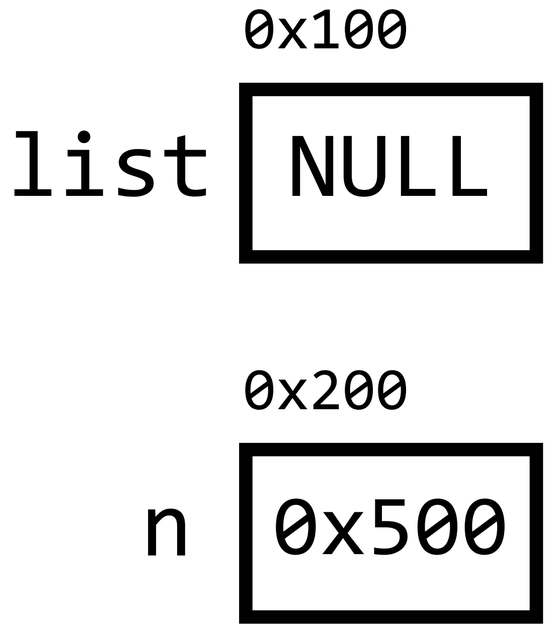


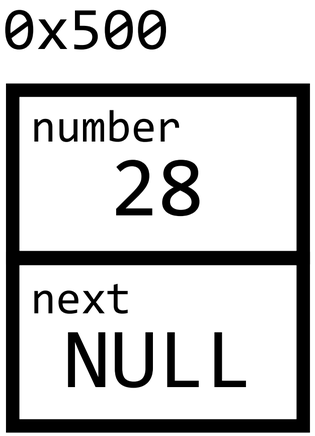
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;
```



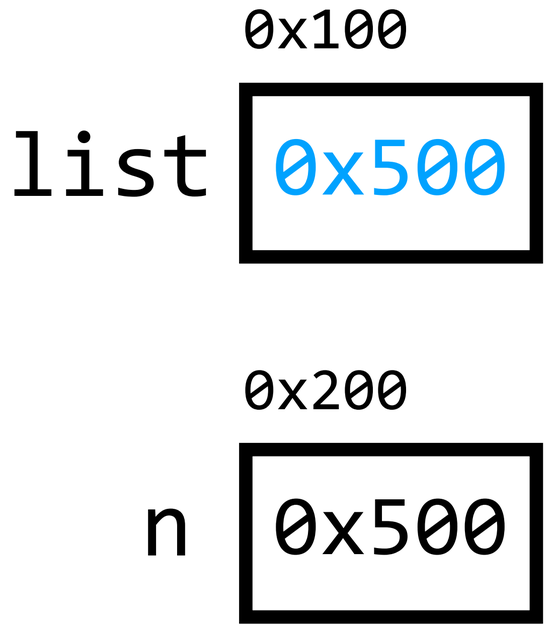


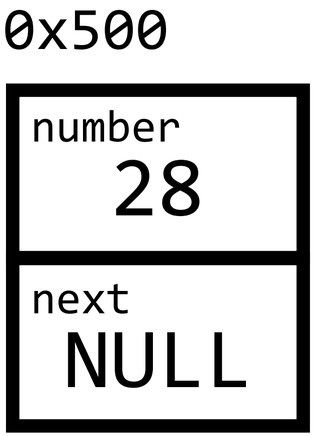
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;
```



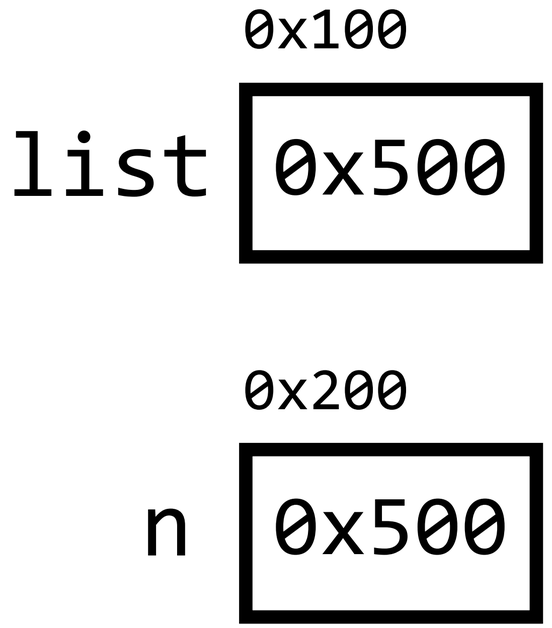


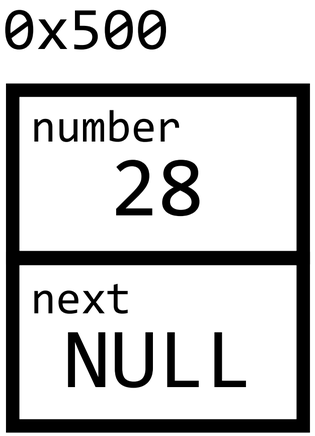
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;
```



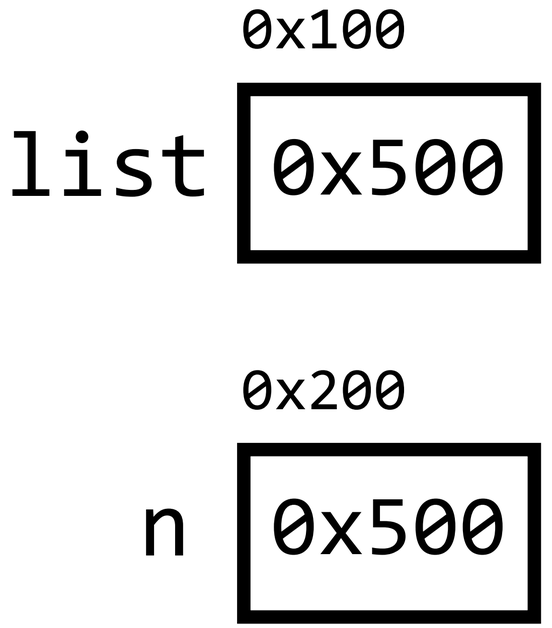


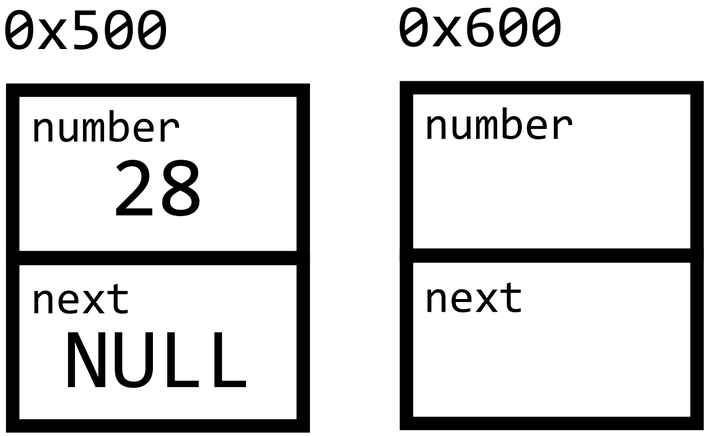
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
```



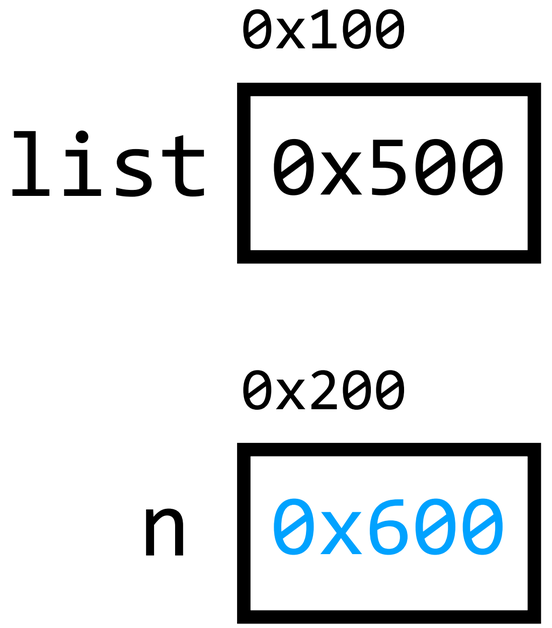


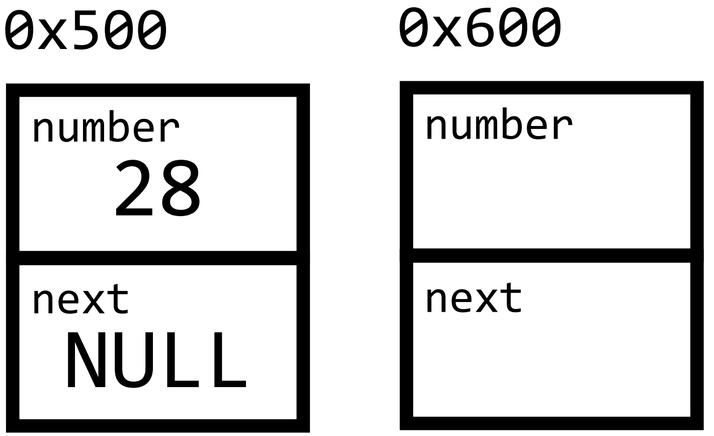
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
```



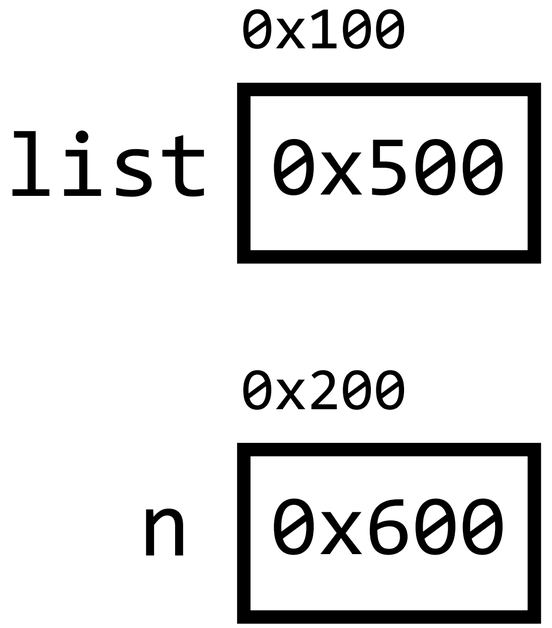


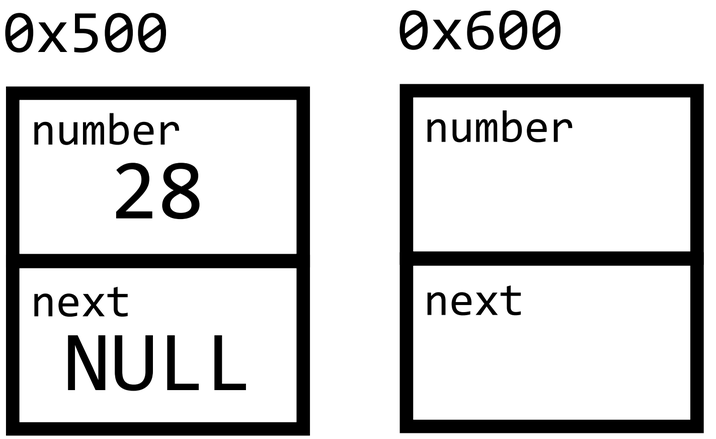
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
```



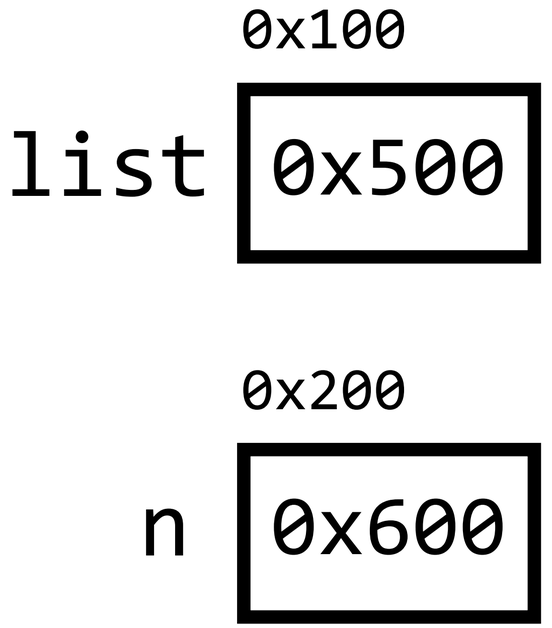


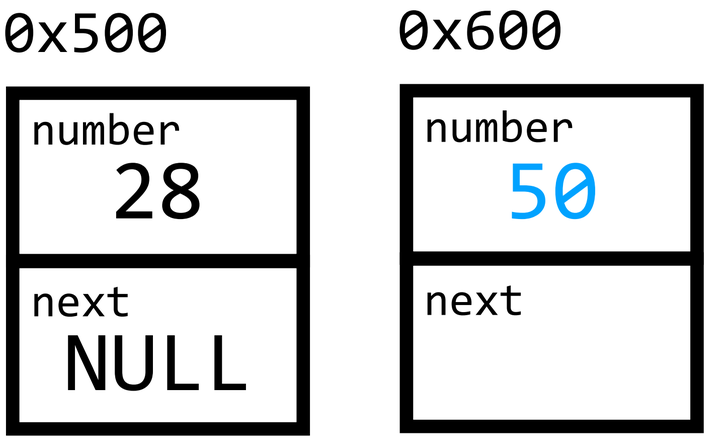
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
```



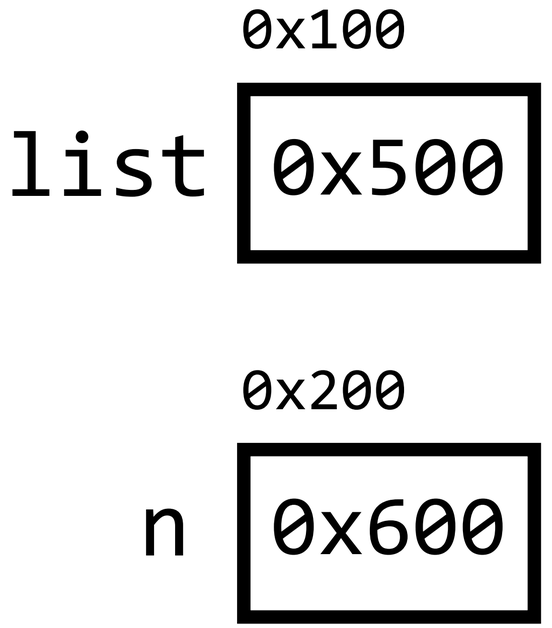


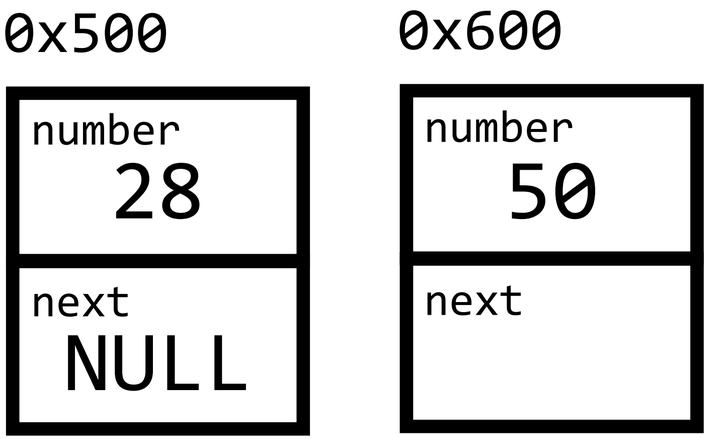
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
```



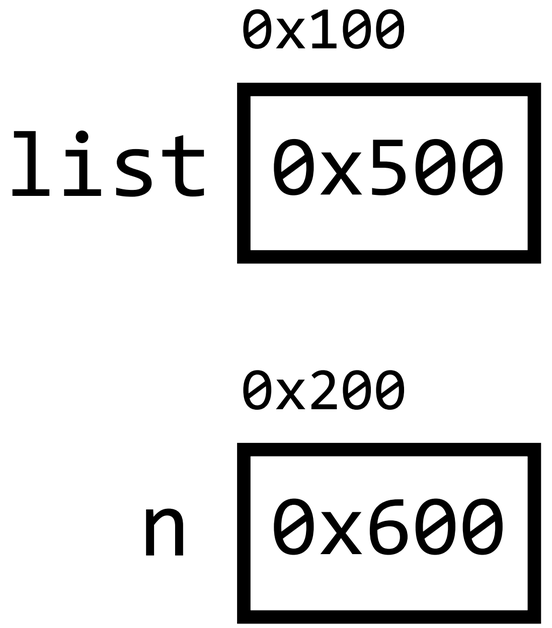


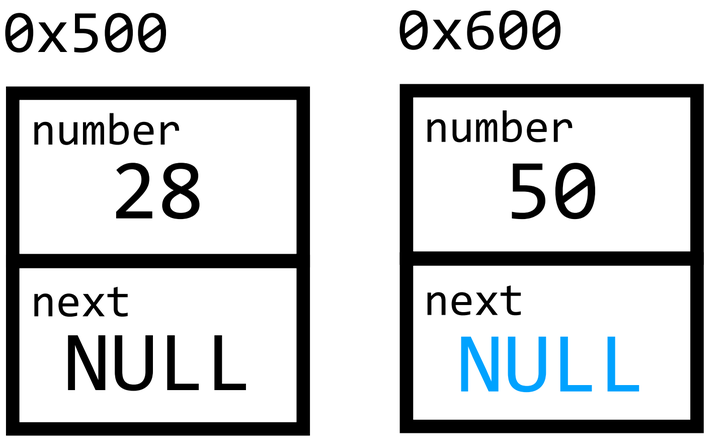
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;
```



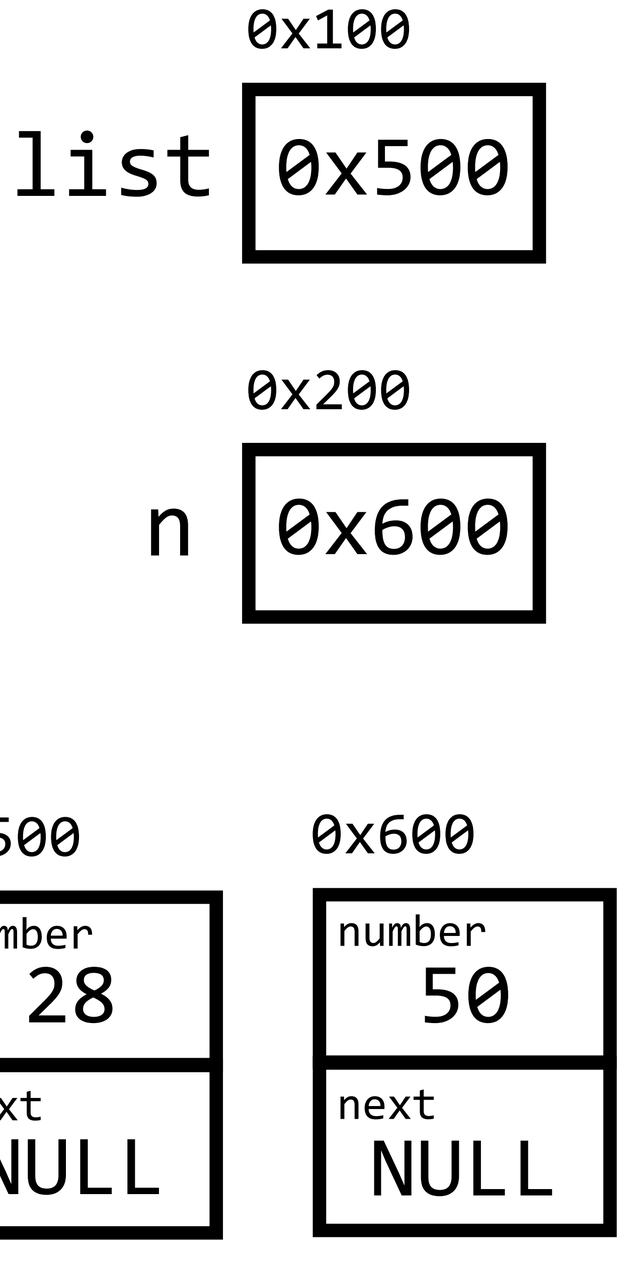


```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;
```

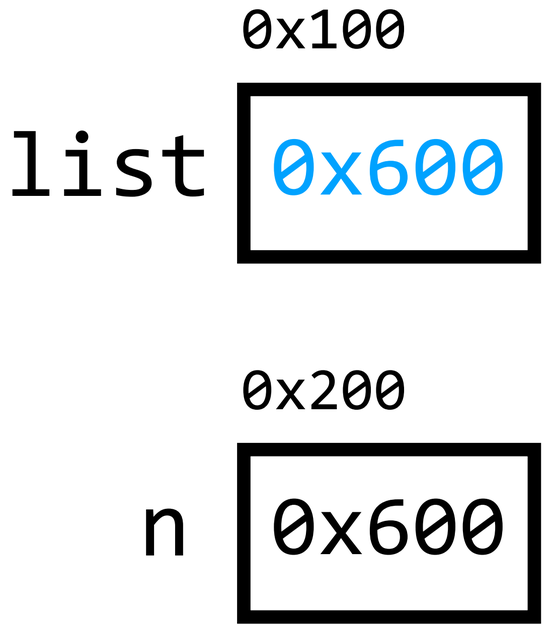


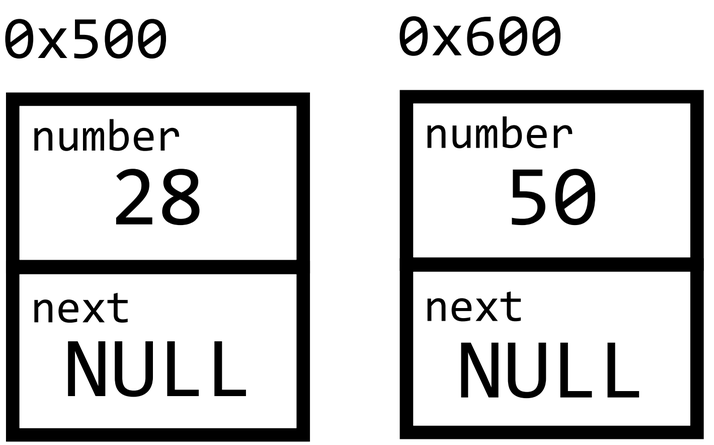


```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

list = n;
```

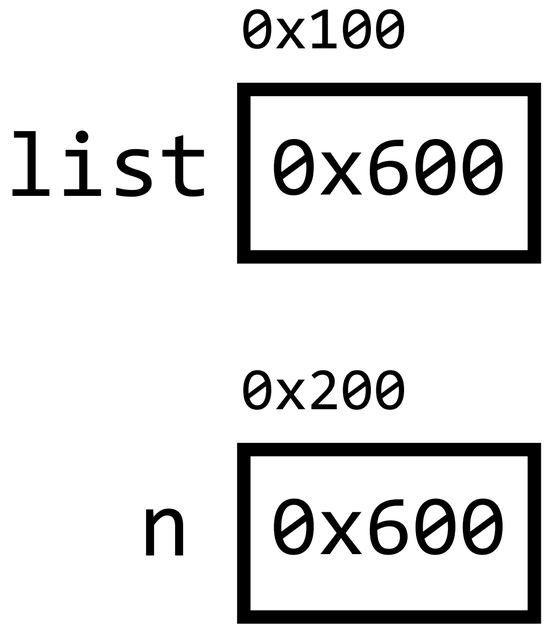


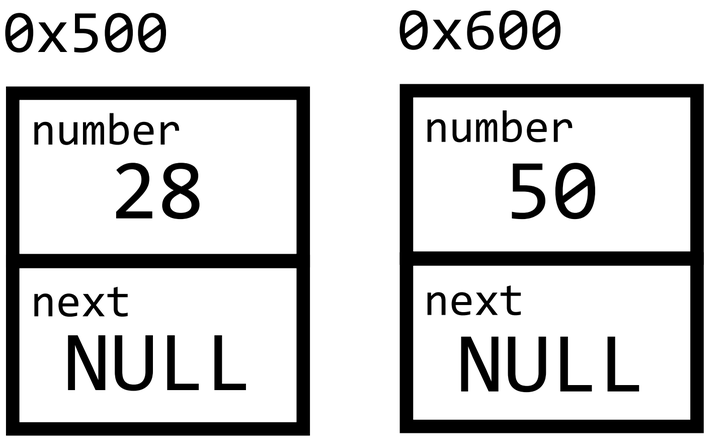
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

list = n;
```



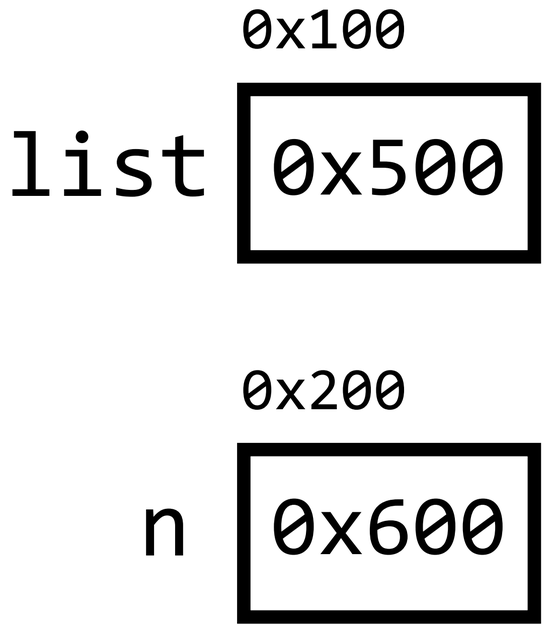


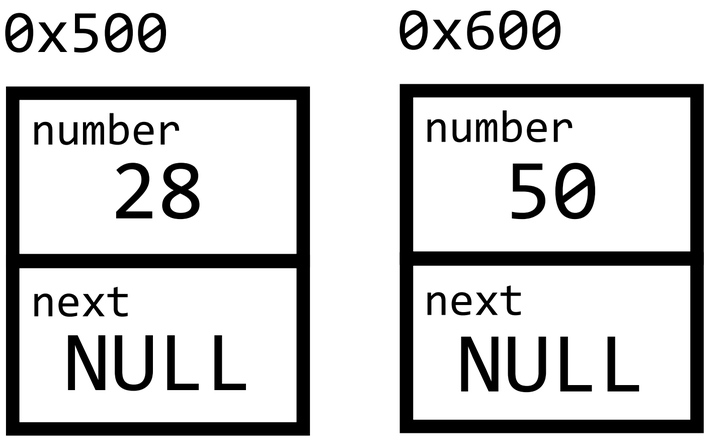
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

list = n;
```



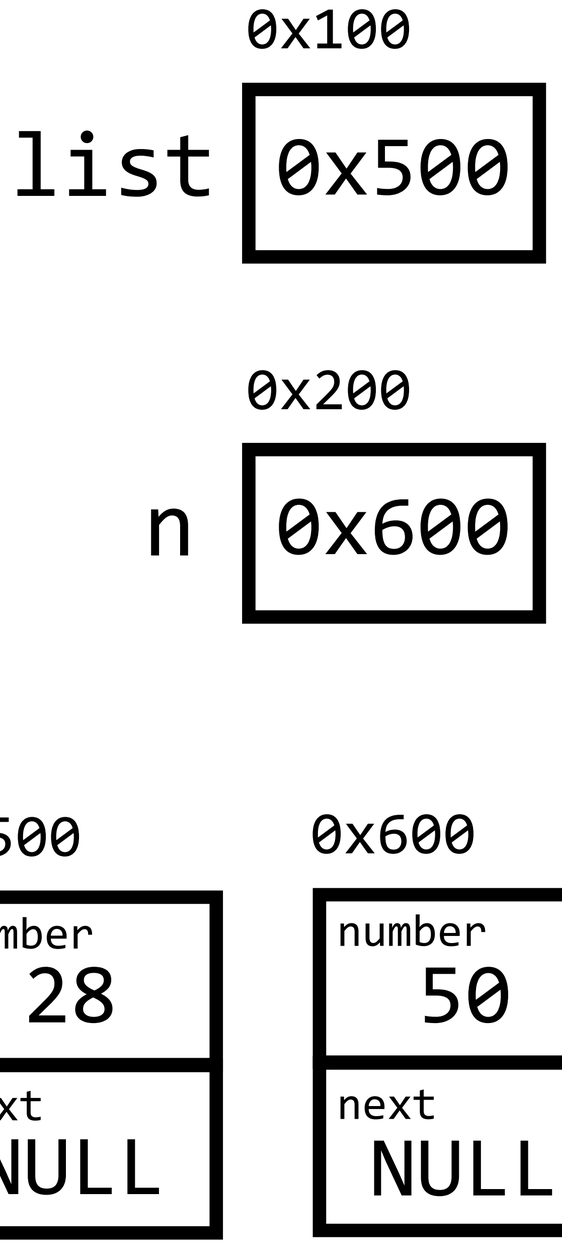


```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;
```

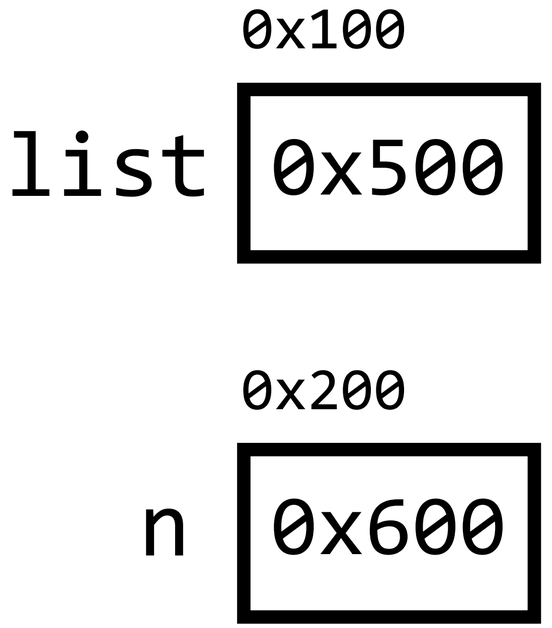


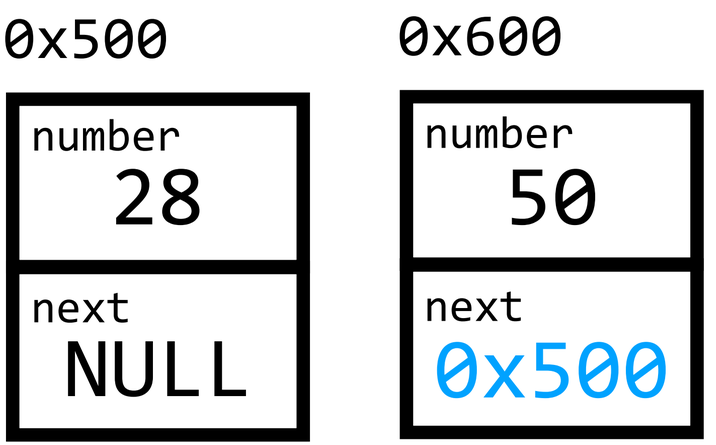


```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

n->next = list;
```

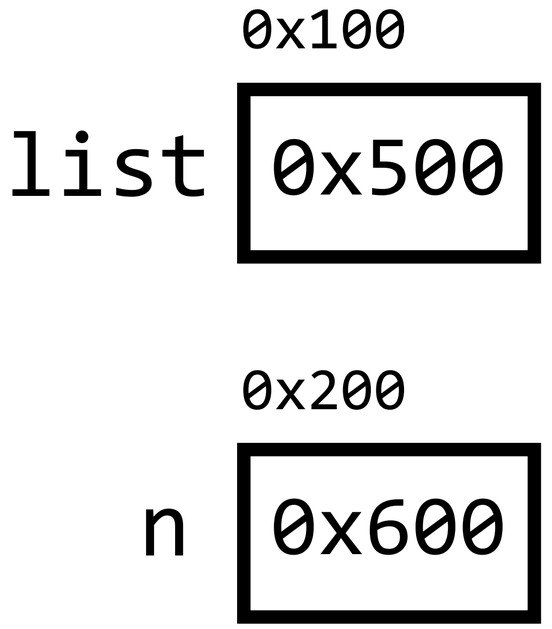


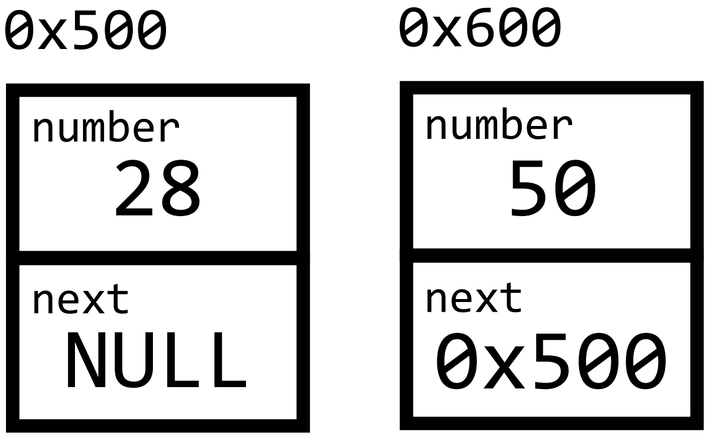
```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

n->next = list;
```



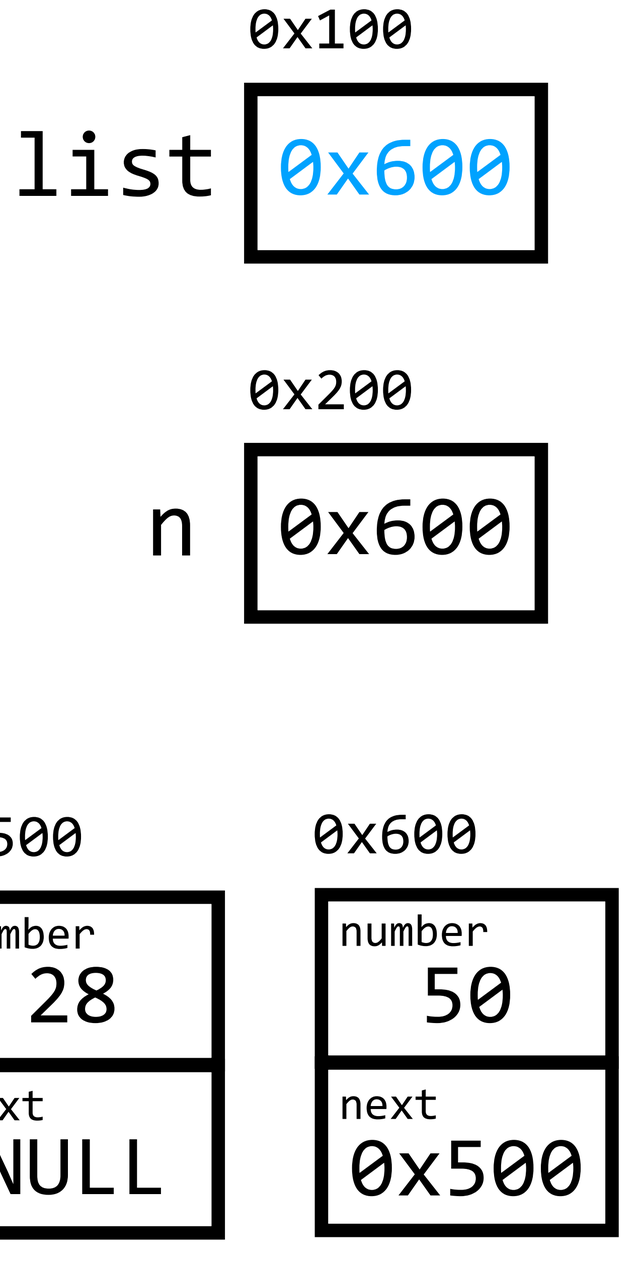


```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

n->next = list;
list = n;
```

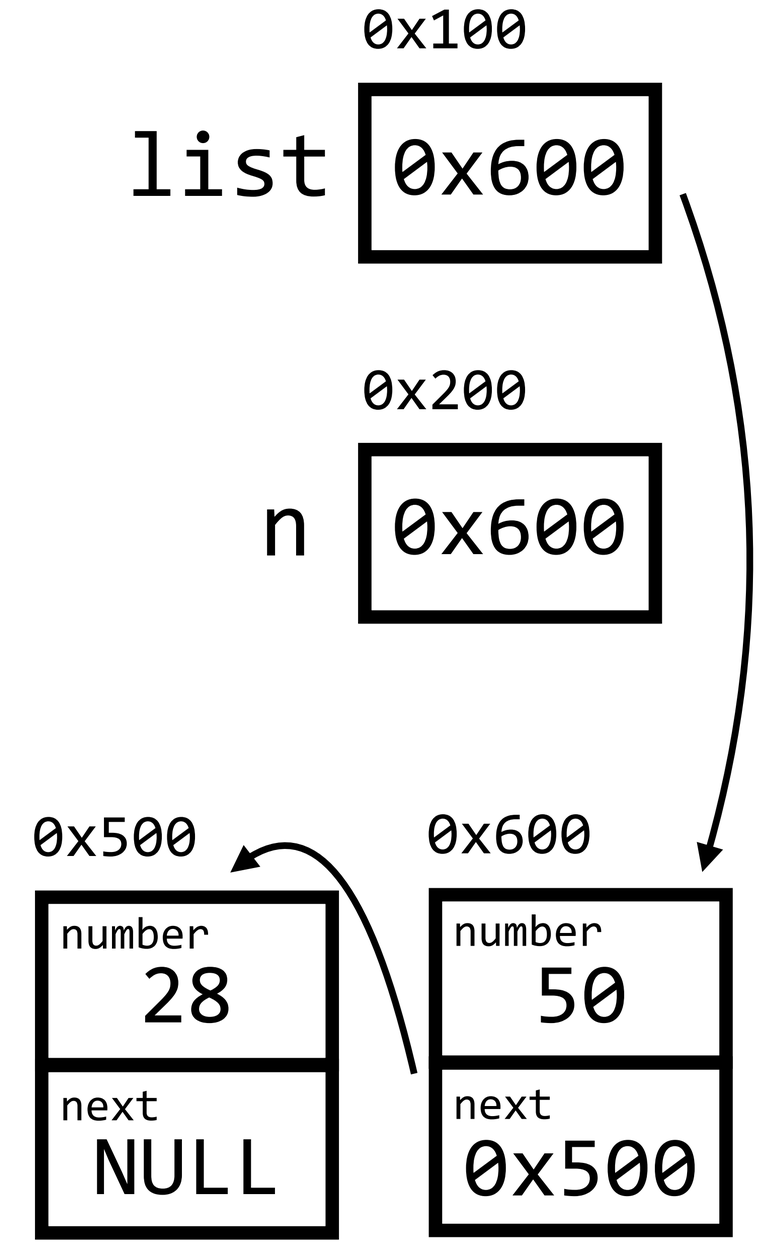




```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

n->next = list;
list = n;
```



```
node *list = NULL;

node *n = malloc(sizeof(node));
n->number = 28;
n->next = NULL;

list = n;

n = malloc(sizeof(node));
n->number = 50;
n->next = NULL;

n->next = list;
list = n;
```



Exercise

Download distribution code at
`wget https://cdn.cs50.net/2020/spring/classes/5/list.c`

Update `list.c` to allocate memory for a new node,
for each number entered by the user.

Be sure to set the `number` of the node,
but no need to link the nodes together yet!

Exercise

Update `list.c` to add each new node to the beginning of the linked list.

Exercise

Update `list.c` to print out all of the nodes, on on each line.

Exercise

Update `list.c` to free all of the nodes.

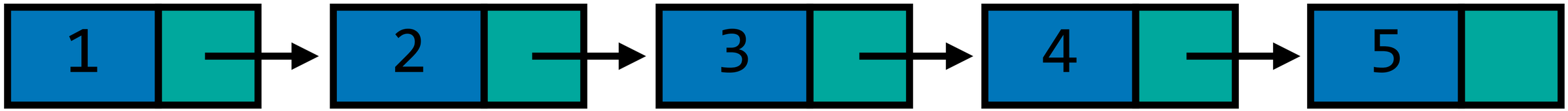
Exercise

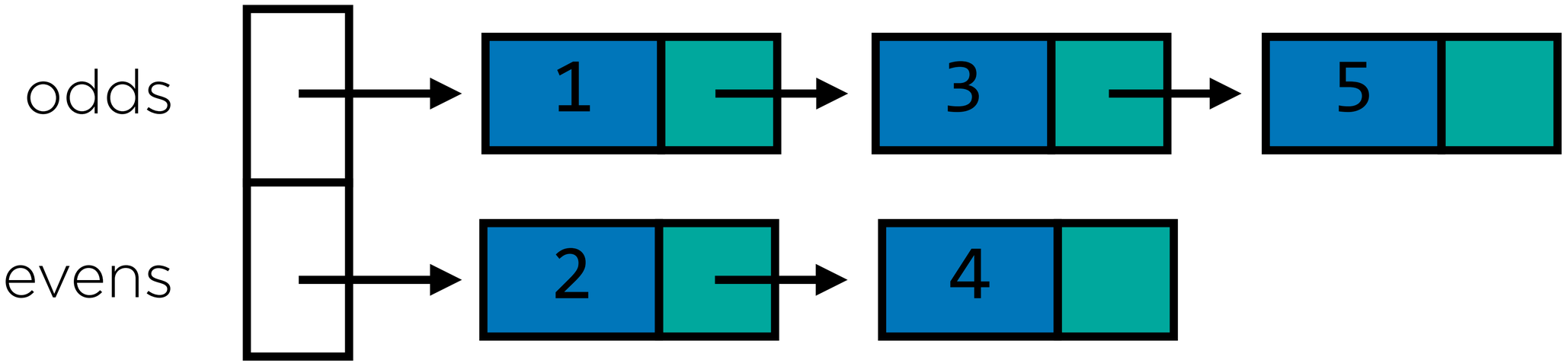
Update `list.c` to add new nodes to the end of the linked list, instead of the beginning.

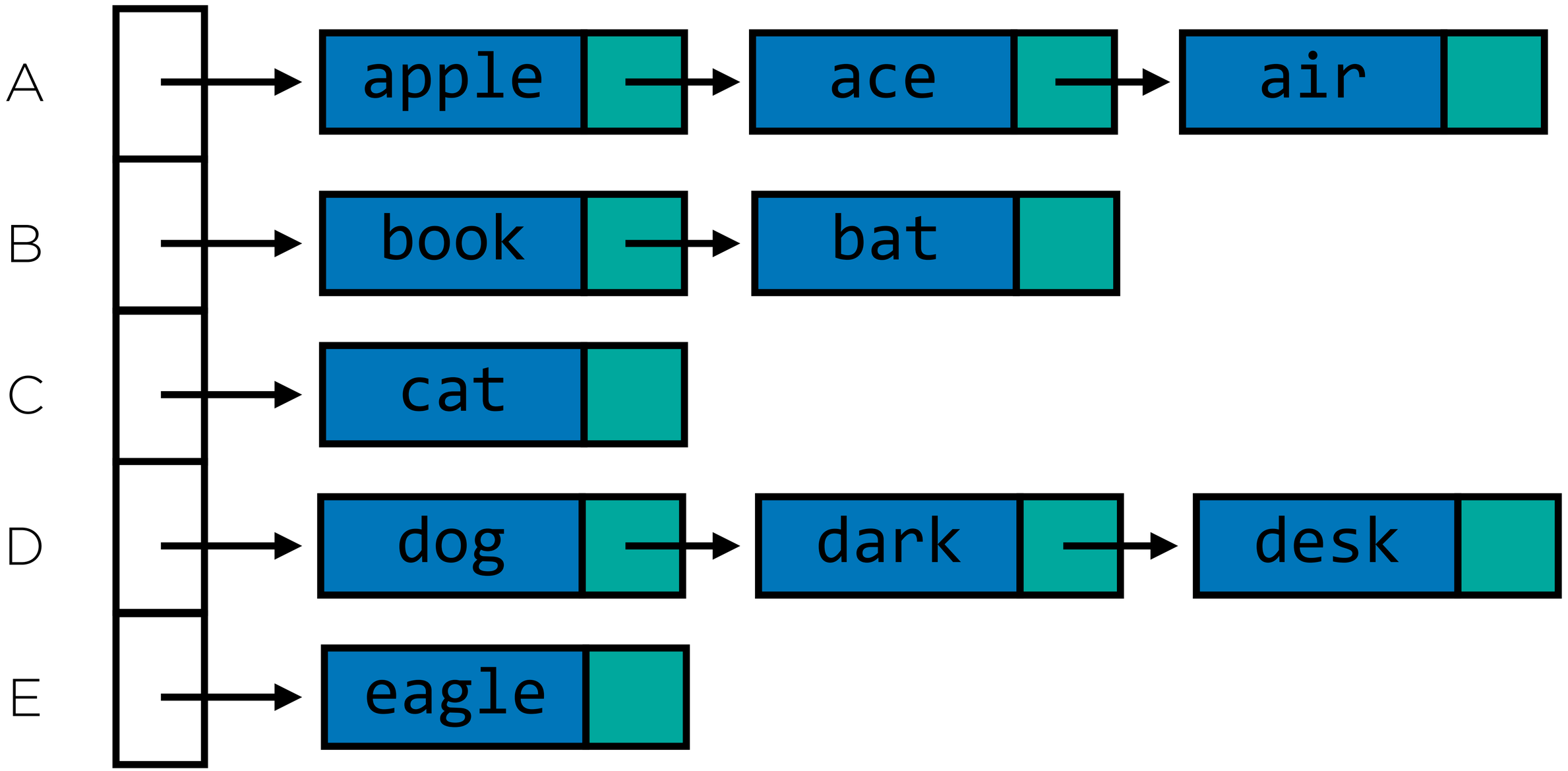
Part Two

Hash Tables

Hash Tables


1
2
3
4
5


odds
evens
1
3
5
2
4


A
B
C
D
E
apple
ace
air
book
bat
cat
dog
dark
desk
eagle

Hash Table

- Array of linked lists
- Use a **hash function** to take an input, and pick a corresponding linked list

```
function hash(char *s)
{
    return s[0] - 'A';
}
```

Hash Function

- Deterministic: always maps same input to the same output
- Minimize collisions: fewer collisions means shorter linked lists

Linked List

```
node *list;
```

Hash Table

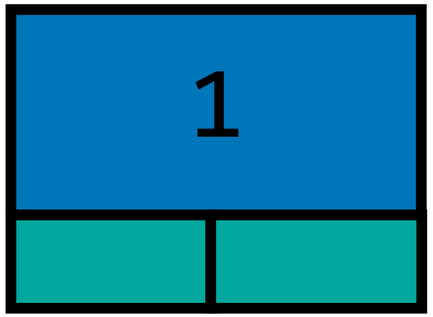
```
node *table[50];
```

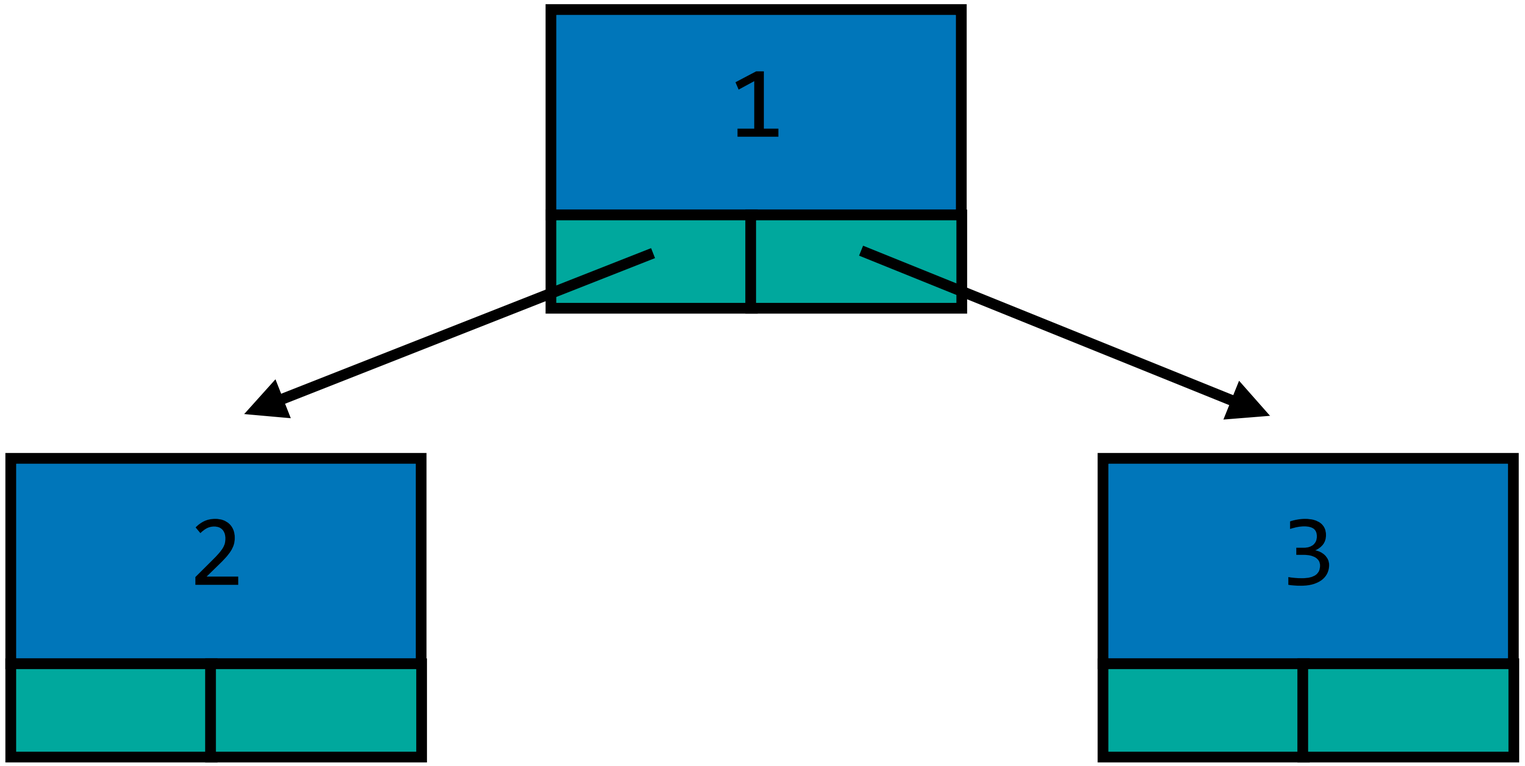
Part Three

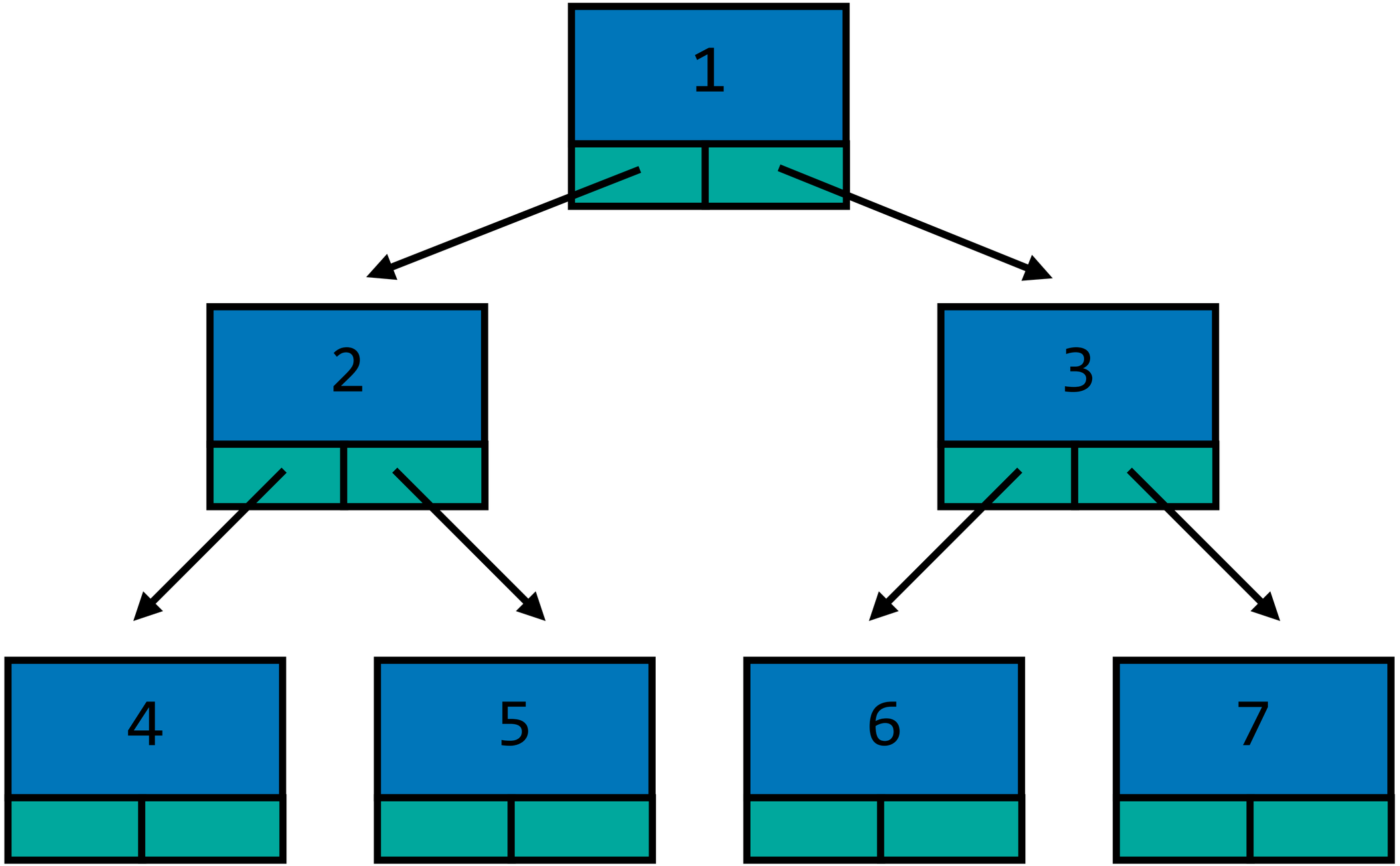
Trees and Tries

Trees

Binary Trees

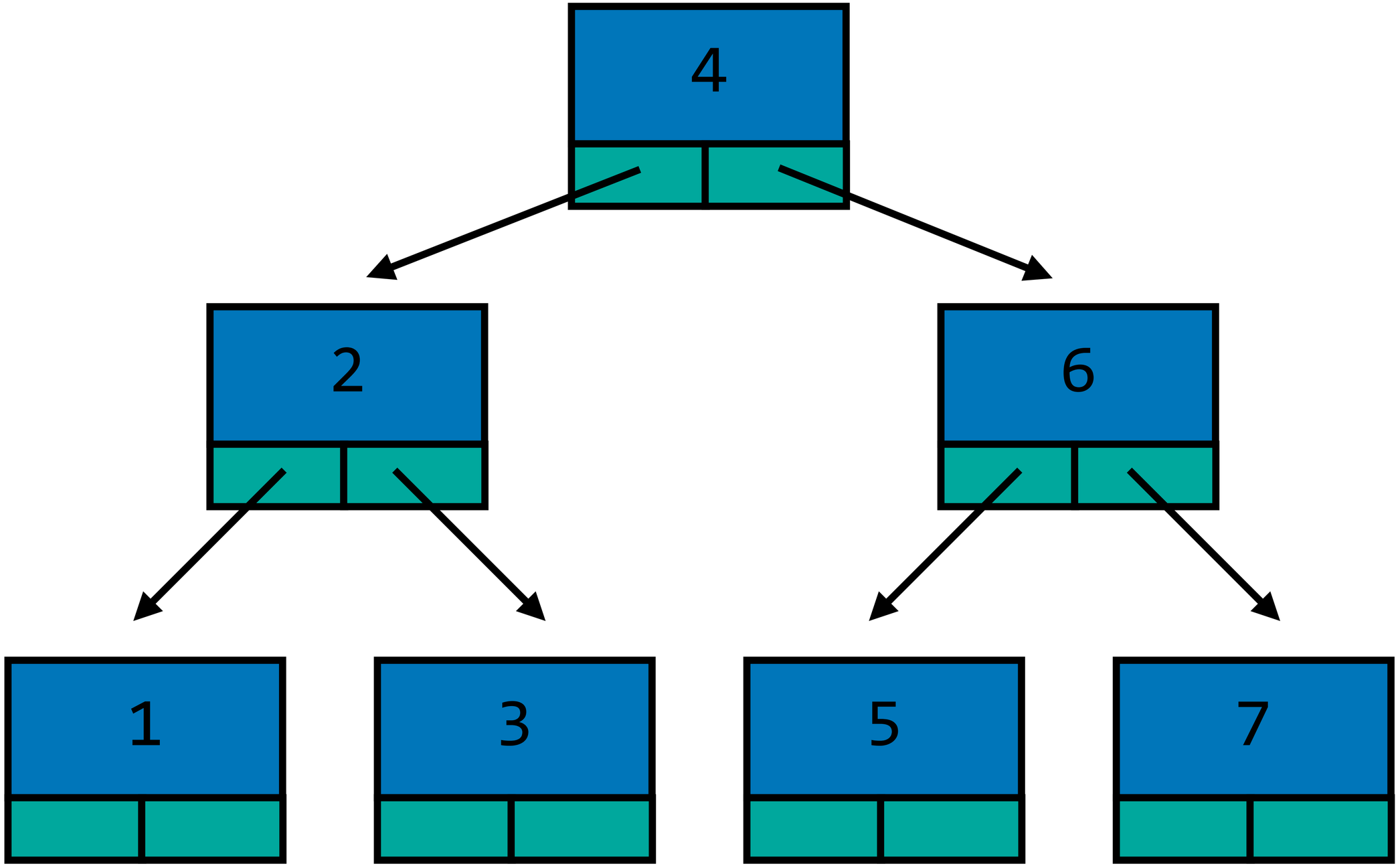

1

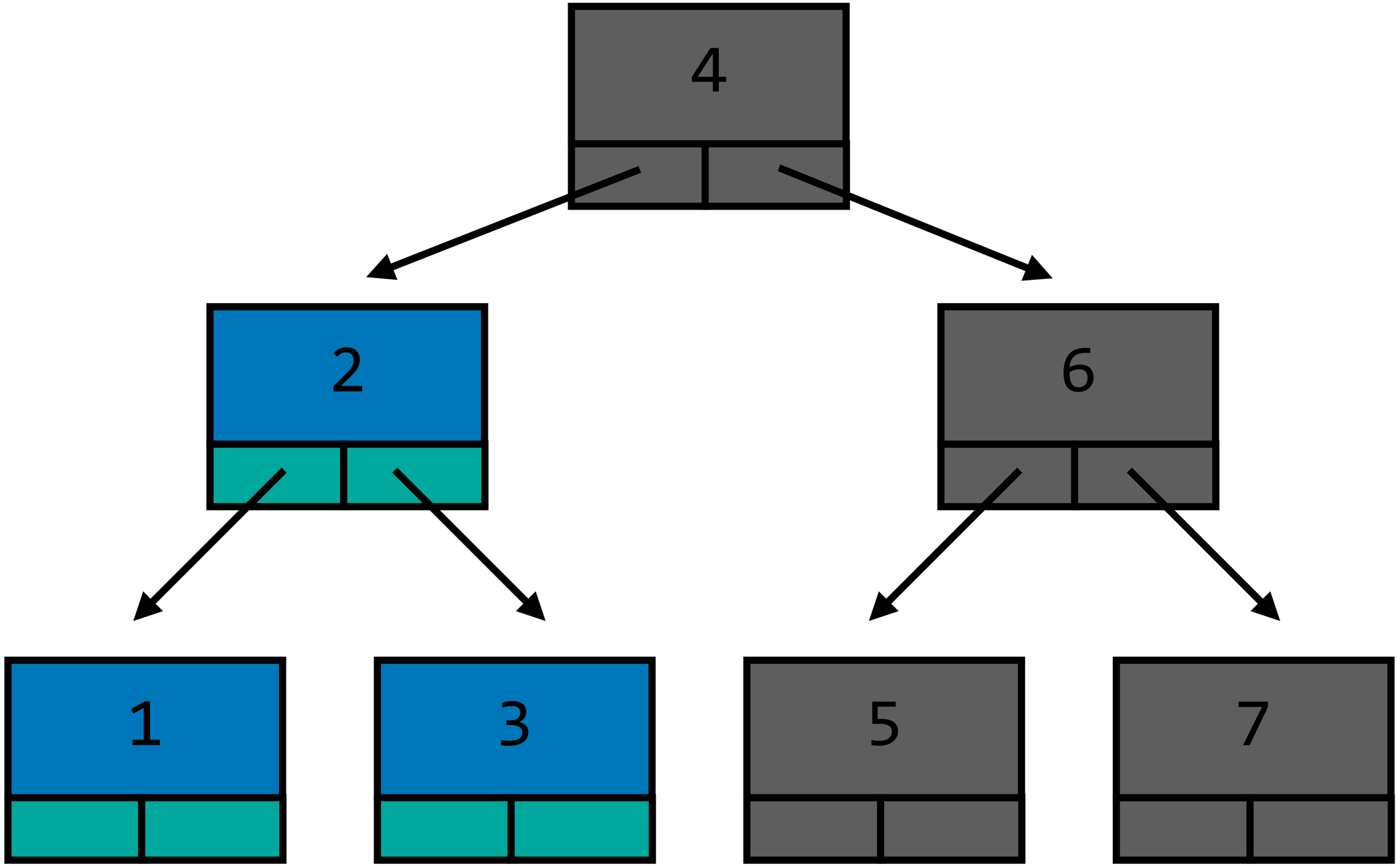

1
2
3

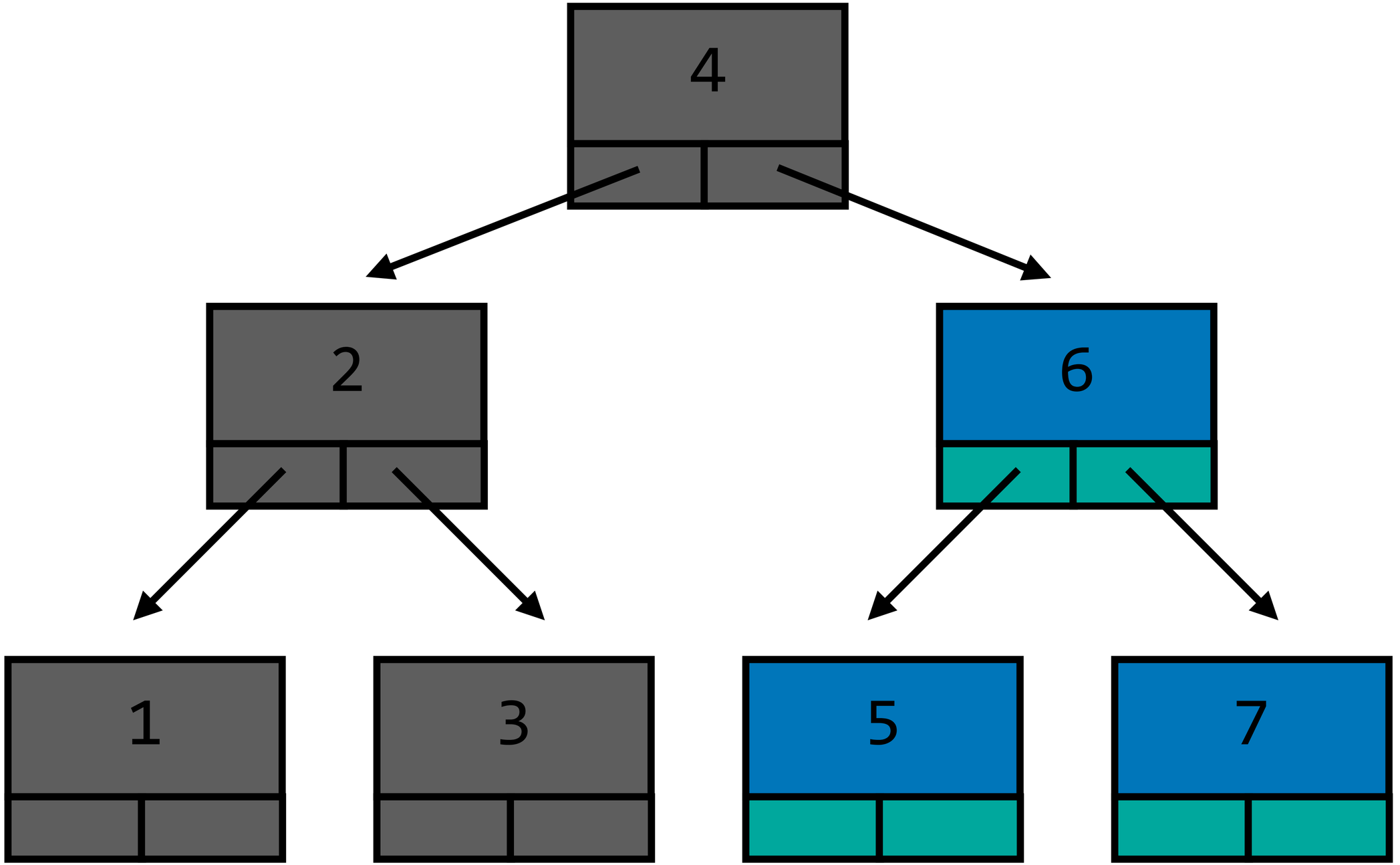

1
2
3
4
5
6
7

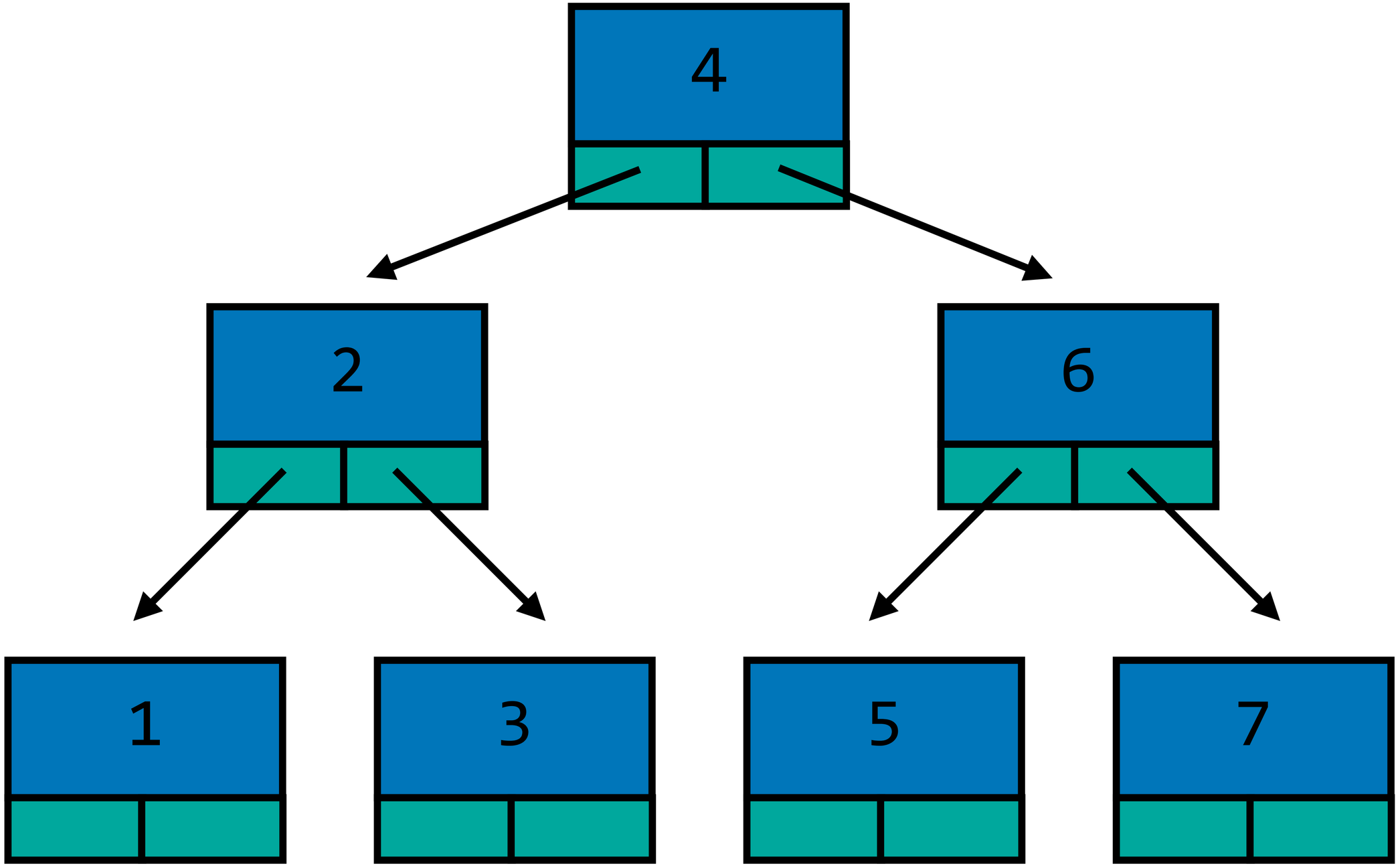
```
typedef struct node
{
    int number;
    struct node *left;
    struct node *right;
}
node;
```

Binary Search Trees

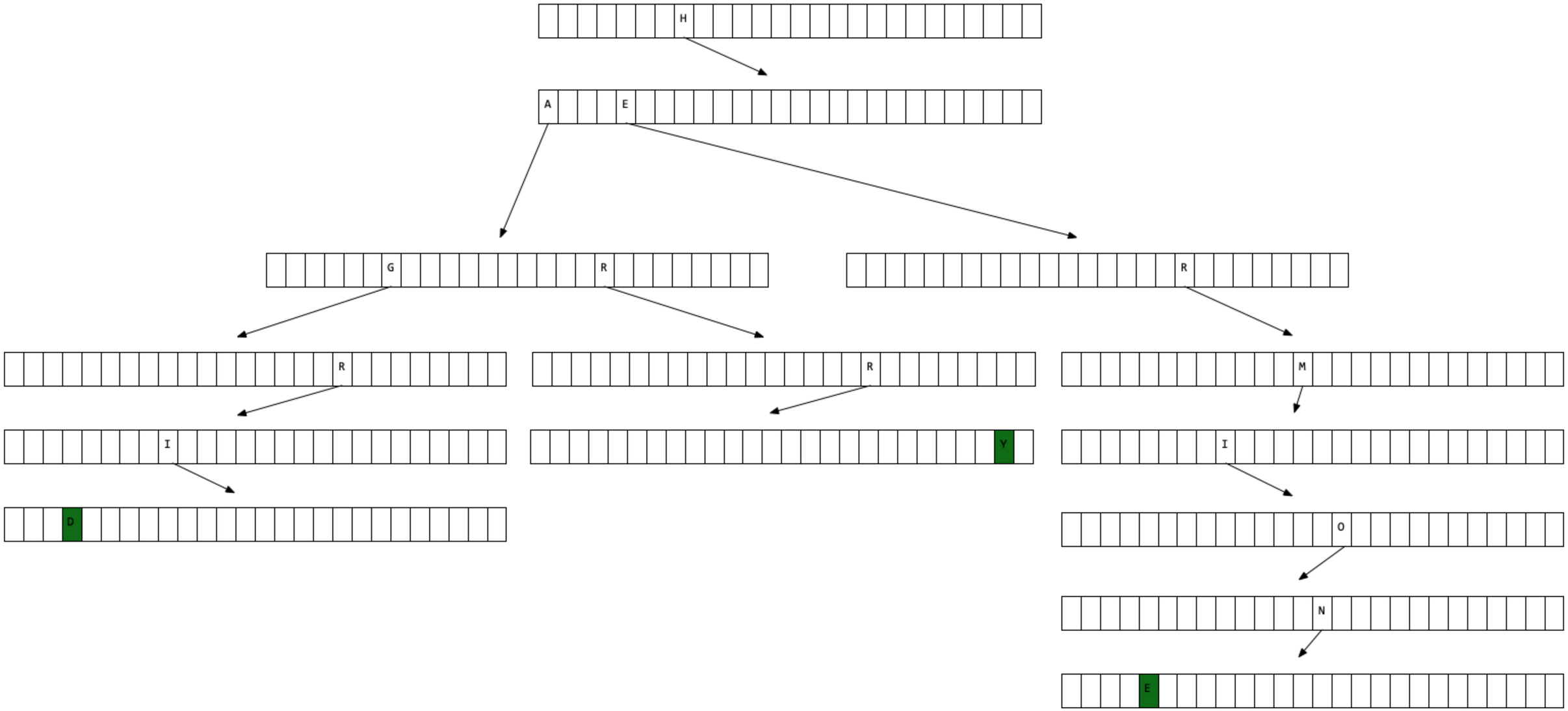

4
2
6
1
3
5
7


4
2
6
1
3
5
7


4
2
6
1
3
5
7


4
2
6
1
3
5
7

Tries


H
A
E
G
R
R
R
R
I
Y
M
D
I
O
N
E

```
typedef struct node
{
    bool word;
    struct node *children[26];
}
node;
```

https://www.cs.usfca.edu/~galles/visualization/Trie.html

Stacks, Queues

Queues

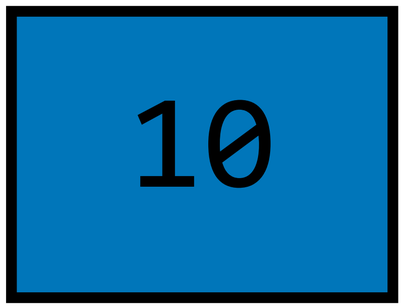
- Enqueue
- Dequeue

Queues

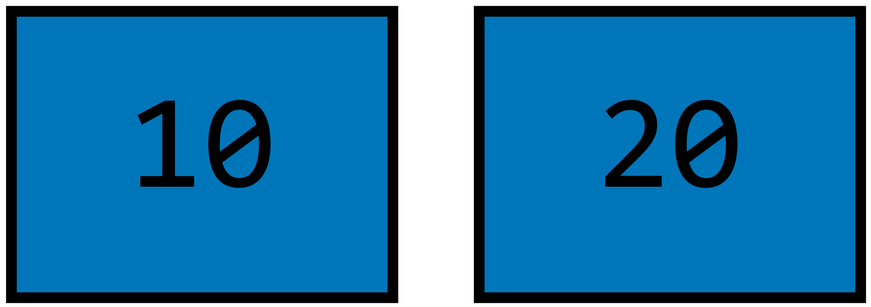
- First In, First Out

Queues

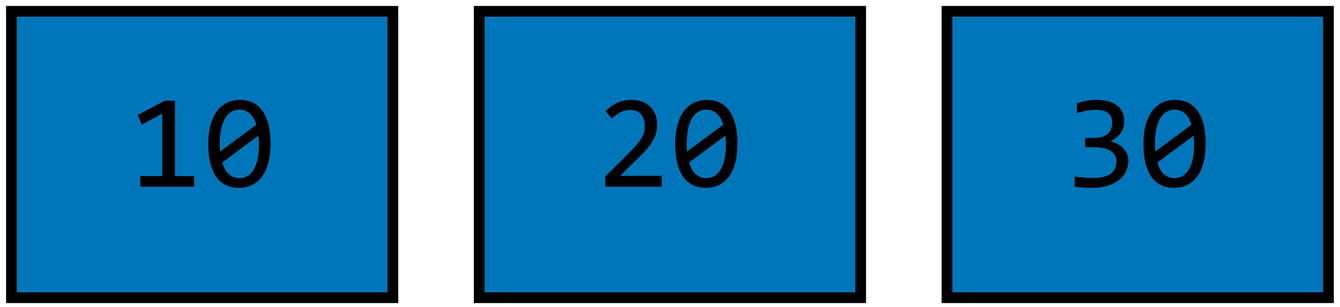
Queues



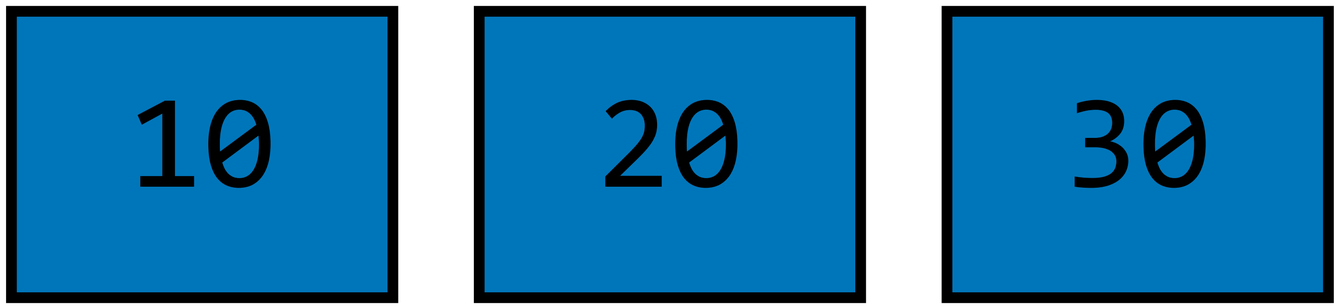
Queues



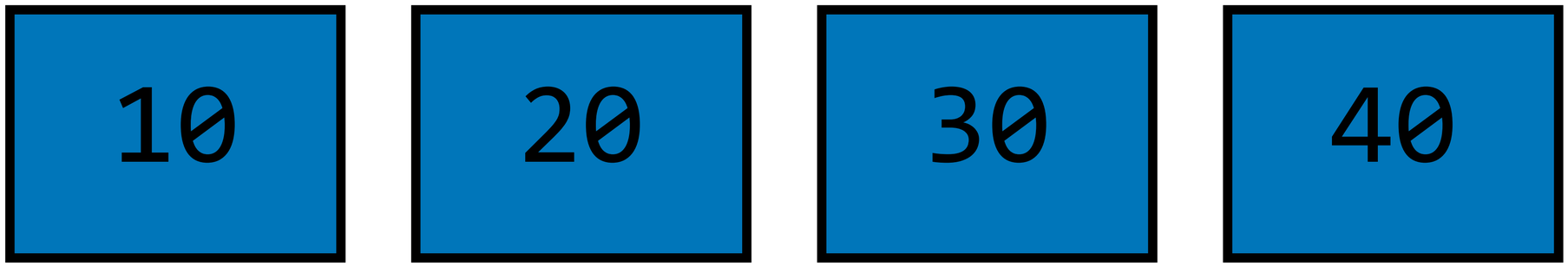
Queues



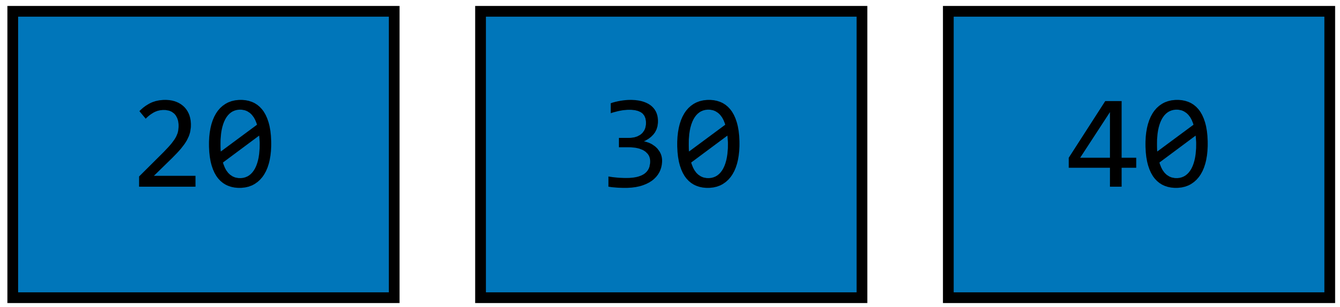
Queues



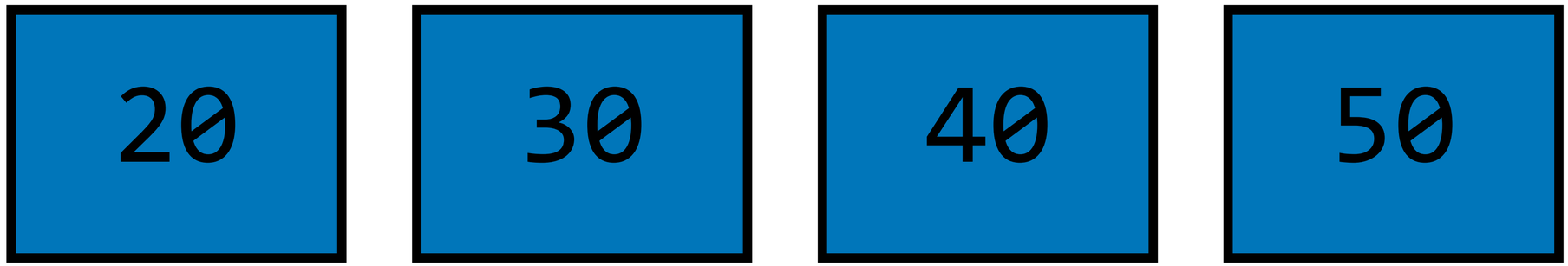
Queues



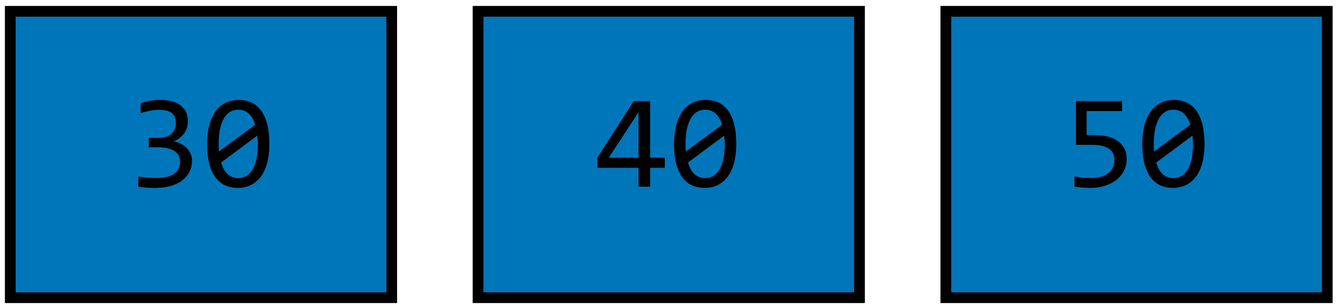
Queues



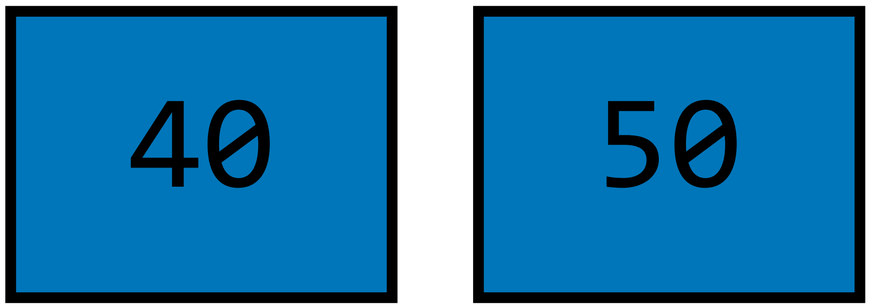
Queues



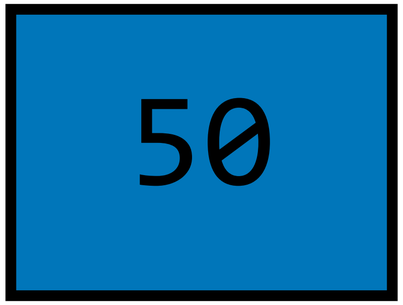
Queues



Queues



Queues



Queues

Stacks

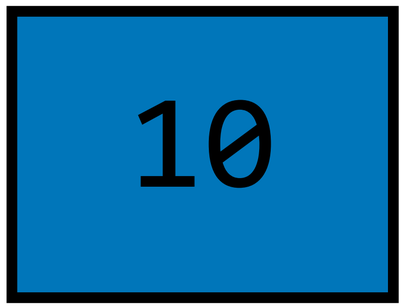
- Push
- Pop

Stacks

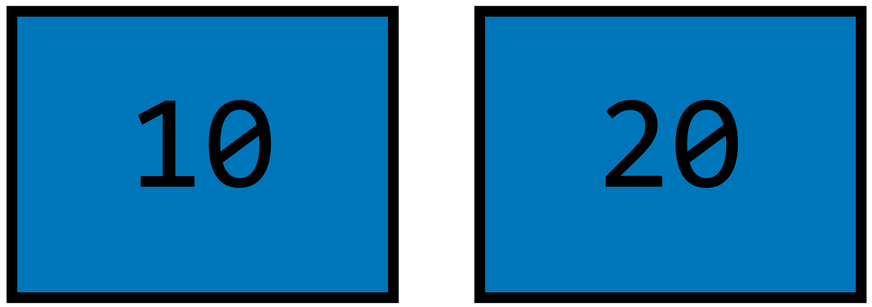
- First In, Last Out

Stacks

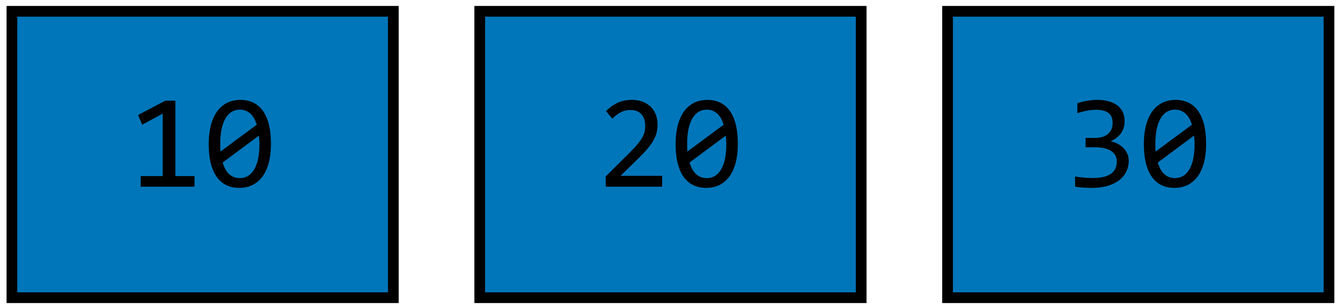
Stacks



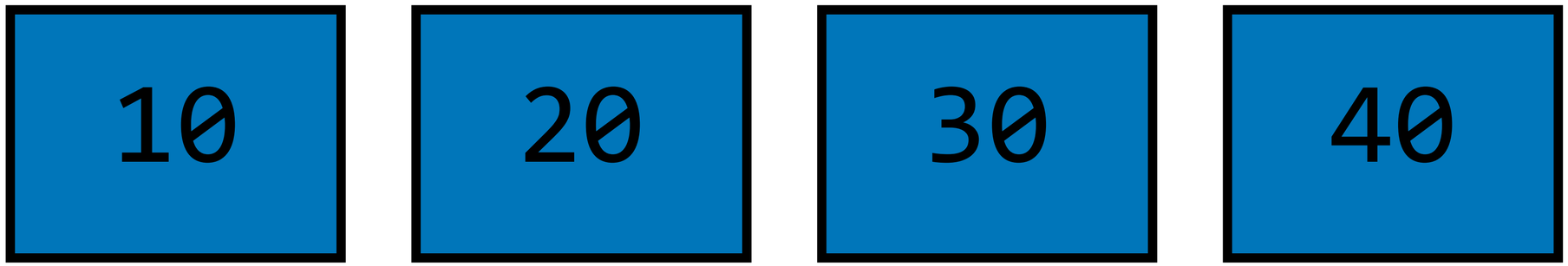
Stacks



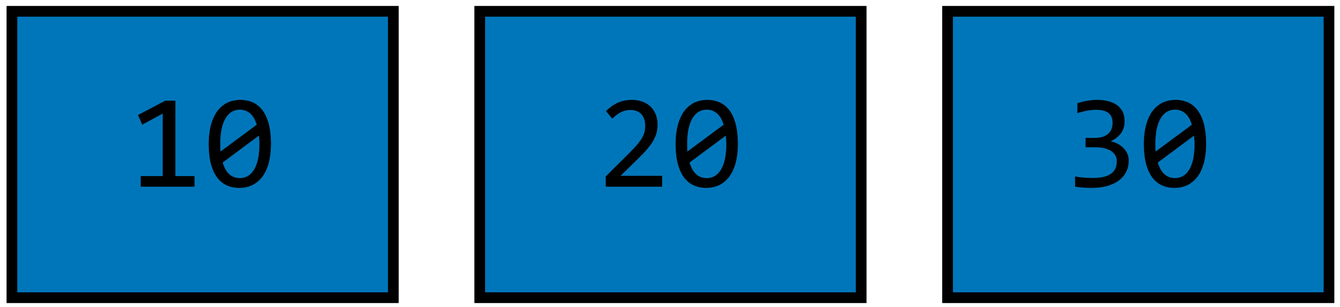
Stacks



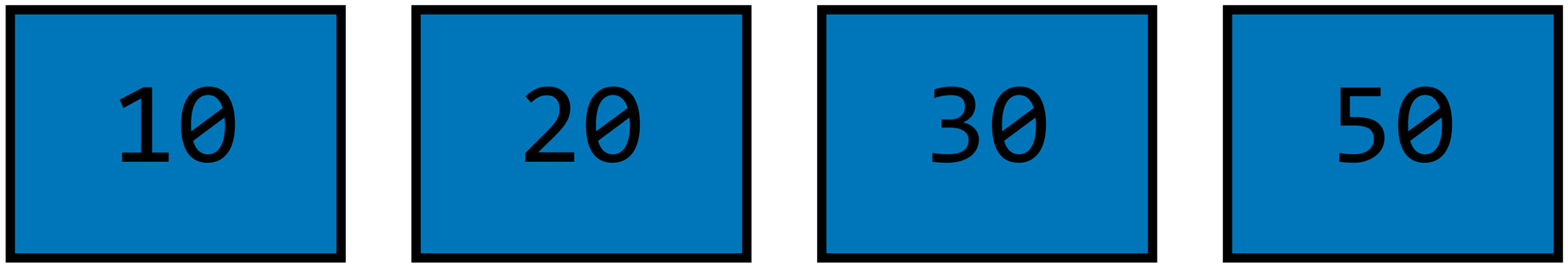
Stacks



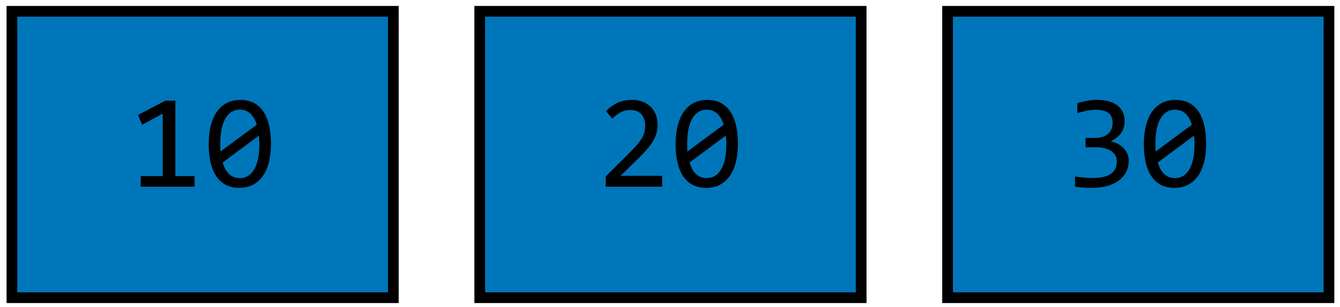
Stacks



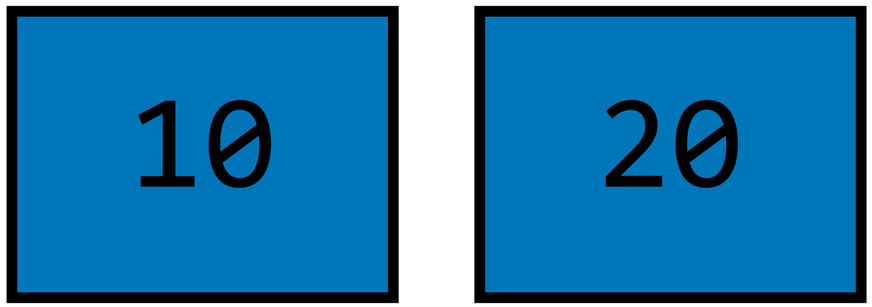
Stacks



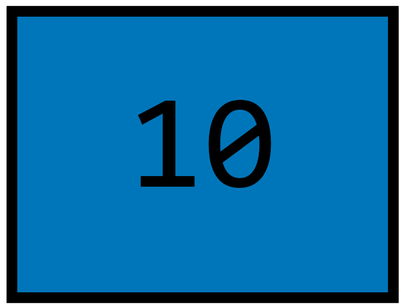
Stacks



Stacks



Stacks

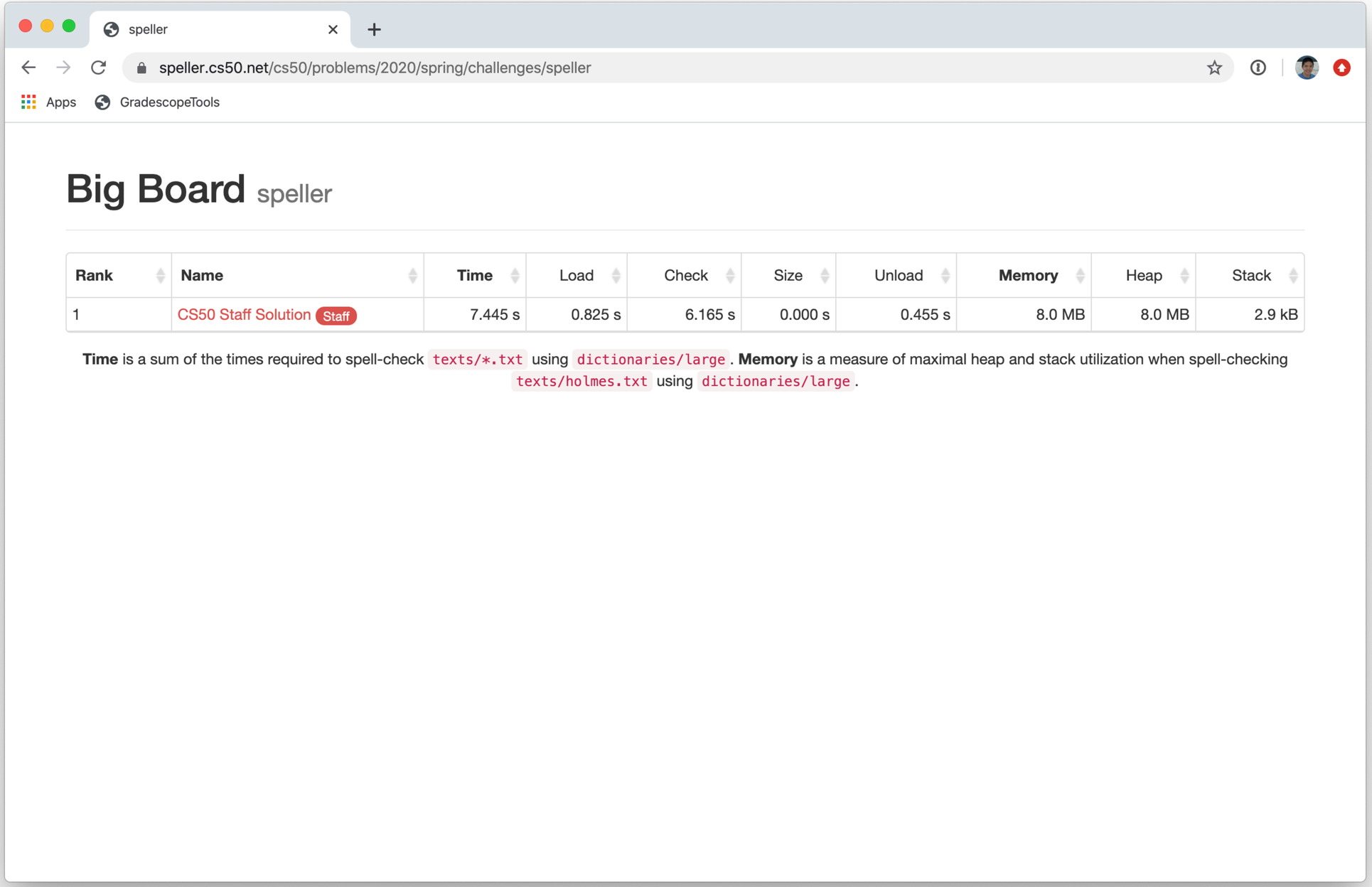


Stacks

Problem Set 5

Problem Set 5

- Speller



Big Board speller

Rank	Name	Time	Load	Check	Size	Unload	Memory	Heap	Stack
1	CS50 Staff Solution Staff	7.445 s	0.825 s	6.165 s	0.000 s	0.455 s	8.0 MB	8.0 MB	2.9 kB

Time is a sum of the times required to spell-check `texts/*.txt` using `dictionaries/large`. **Memory** is a measure of maximal heap and stack utilization when spell-checking `texts/holmes.txt` using `dictionaries/large`.

This is CS50.